

***Aster alpinus* L. var. *vierhapperi*  
(Onno) Cronquist  
(Vierhapper's aster):  
A Technical Conservation Assessment**



**Prepared for the USDA Forest Service,  
Rocky Mountain Region,  
Species Conservation Project**

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## COVER PHOTO CREDIT

*Aster alpinus* var. *vierhapperi* (Vierhapper's aster). Photograph by Loraine Yeatts. Reprinted with permission from the photographer.

# SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *ASTER ALPINUS* VAR. *VIERHAPPERI*

## *Status*

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). *Aster alpinus* var. *vierhapperi* (Vierhapper's aster) occurs across Canada, Alaska, and into the middle Altai Mountains of central Asia, a broad region, which can be considered its primary range. The variety is represented by six disjunct occurrences in Colorado and Wyoming in USFS Region 2 and by four disjunct occurrences in Idaho in USFS Region 4. Of these ten occurrences, nine are on National Forest System lands. *Aster alpinus* var. *vierhapperi* is typically located in the alpine occupying suitable habitat in the high mountains near the continental divide and less often in montane areas.

The variety is not federally listed or a candidate for listing under the Endangered Species Act, nor is it designated a sensitive species on National Forest System lands. The global heritage status rank for the species and variety is G5T5 (common, widespread, and abundant), and its national heritage status rank in the United States is NNR (nation conservation status not yet assessed). In Colorado, *Aster alpinus* var. *vierhapperi* is classified as S1 (critically imperiled). In Wyoming and Idaho, occurrences of *A. alpinus* var. *vierhapperi* were only recently (during the writing of this assessment) documented and brought to the attention of the USFS and the Wyoming Natural Diversity Database (WYNDD). According to WYNDD, the new occurrence from Park County, Wyoming, which was collected in 1979, will result in an automatic S1S? rank for the taxon (an inexact or uncertain rank but likely critically imperiled). The Idaho Natural Heritage Program will review the taxon in that state, and if the results of the review concur that the *A. alpinus* var. *vierhapperi* occurs in Idaho, then it will also be given a S1 (critically imperiled) designation. The Alaska Natural Heritage Program reports approximately 10 occurrences across a wide area and designates it as S2 (imperiled). In Canada rankings are variable. In Alberta and the Northwest Territories the taxon is not ranked; in Ontario it is ranked S1 (critically imperiled); in British Columbia it is ranked S3S4 (vulnerable to apparently secure); in the Yukon it is ranked S4S5 (apparently secure to common, widespread, abundant).

## *Primary Threats*

*Aster alpinus* var. *vierhapperi* is vulnerable on National Forest System lands because of the small number of occurrences and its disjunct distribution in North America. Possible threats include loss of habitat or individuals due to human-related activities such as grazing, mining, and recreational activities such as off-road vehicle use, snowmobiles, camping, and hiking. Occurrences of *A. alpinus* var. *vierhapperi* may also be at risk from environmental or demographic stochasticity due to small neighborhood size of populations. Threats to reproductive processes, such as inadequate pollinator activity, possible outbreeding depression through a hybridization event, lack of safe sites for germination or seedling establishment, and unknown barriers to gene flow, may pose risks to this taxon. Environmental threats include global warming, nitrogen deposition, and residue from cloud seeding operations.

## *Primary Conservation Elements, Management Implications, and Considerations*

*Aster alpinus* var. *vierhapperi* has limited abundance and a disjunct distribution on National Forest System lands, generating a concern for its viability within Region 2. Of the nine occurrences reported in the contiguous United States, only two have been observed in the past twenty years, one on the Arapaho National Forest in Colorado and one at Golden Gate State Park, also in Colorado. Despite the fact that *A. alpinus* var. *vierhapperi* is considered to be secure on a global basis, further inventory, monitoring, and conservation actions would be valuable for this taxon and its habitat that occurs on the southern edge of its range in Region 2.

There is no information concerning the microhabitat requirements for this taxon, success of reproduction (sexual or asexual), or range of genetic variability, nor is there information concerning the ability of the variety to adapt to changing environmental conditions.

Surveying potential habitat for new occurrences, protecting existing occurrences from negative impacts, documenting and monitoring the effects of current land-use activities, and preventing non-native plant invasions are key conservation elements for *Aster alpinus* var. *vierhapperi*. Priorities of future inventory and research studies include re-visiting, estimating size of, and assessing imminent threats to existing occurrences; investigating factors that affect microhabitat characteristics; exploring ecological limitations; and characterizing reproductive mechanisms, population structure, demography, and genetic variability. If significant threats to known occurrences are found, then management actions may be needed to conserve the species.

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## INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). *Aster alpinus* var. *vierhapperi* (Vierhapper's aster) is the focus of an assessment because of its limited regional distribution and abundance on National Forest System lands. Additionally, there is limited knowledge concerning its habitat and population trends, and threats to the taxon. Knowledge of the biology and ecology of *A. alpinus* var. *vierhapperi* would aid in the management decision-making process.

This assessment addresses what is known about the biology and ecology of *Aster alpinus* var. *vierhapperi* throughout its range in North America and on National Forest System lands in Region 2. The broad nature of the assessment leads to some constraints on the specificity of information for particular locales. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

### *Goal*

Species assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, and conservation status of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations. Rather, it provides the ecological background upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications).

### *Scope*

This assessment examines the biology, ecology, conservation status, and management of *Aster alpinus* var. *vierhapperi* with specific reference to the geographic and ecological characteristics of occurrences on National Forest System lands within Region 2. Although some of the literature on the taxon may originate from field investigations outside the region, this document places that literature in the ecological and social contexts of the central Rocky Mountains. Similarly, this assessment is concerned

with reproductive behavior, population dynamics, and other characteristics of *A. alpinus* var. *vierhapperi* in the context of the current environment. The evolutionary environment of the taxon is considered in conducting the synthesis, but placed in a current context.

In producing the assessment, the authors reviewed refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies. The assessment emphasizes refereed literature because this is the accepted standard in science. However, very little information concerning *Aster alpinus* var. *vierhapperi* exists in the primary literature. Refereed literature was available for the discussion of systematics and morphological descriptions. Some of the refereed literature was published in a foreign language; consequently, the authors were unable to use it directly. However, the content of this literature was explained in other refereed articles, and both authors were cited. No refereed literature specifically concerning population trends, autecology, reproductive characteristics, or demography of *A. alpinus* var. *vierhapperi* was located. Non-refereed publications or reports were regarded with greater skepticism, but these materials were used when refereed literature was lacking. Unpublished data (e.g., state natural heritage program records) were important in estimating the geographic distribution and abundance of this taxon. These data required special attention because of the diversity of persons and methods used in collection. Some data for the species assessment were obtained by secondary sources including the Colorado Natural Heritage Program (CNHP), herbarium specimen label data, scientific literature, and knowledgeable individuals. Fifty-three herbaria within Region 2 and surrounding states were contacted. Due to the rarity of the taxon within Region 2, however, only three herbaria responded with pertinent data; these include the Rocky Mountain Herbarium, Laramie, Wyoming (RM); Kathryn Kalmbach Herbarium, Denver, Colorado (KHD); and University of Colorado Museum, Boulder, Colorado (COLO). Literature of closely related taxa was reviewed, and inferences were drawn where reasonable and when a basis could be established for application to *A. alpinus* var. *vierhapperi*. The authors present no empirical data. Measurements are presented in metric (elevations rounded to the nearest 50 m) and standard units (elevations rounded to the nearest 1,000 ft.).

### *Treatment of Uncertainty*

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against

observations. However, because our descriptions of the world are always incomplete and observations limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, strong inference, as described by Platt, suggests that experiments will produce clean results (Hilborn and Mangel 1997) as may be observed in certain physical sciences. The geologist T.C. Chamberlain (1897) suggested an alternative approach to science where multiple competing hypotheses are confronted with observation and data. Sorting among alternatives may be accomplished using a variety of scientific tools (e.g., experiments, modeling, logical inference). Ecological science is, in some ways, more similar to geology than physics because of the difficulty in conducting critical experiments and the reliance on observation, inference, good thinking, and models to guide understanding of the world (Hilborn and Mangel 1997).

Confronting uncertainty, then, is not prescriptive. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate. While well-executed experiments represent a strong approach to developing knowledge, alternative approaches such as modeling, critical assessment of observations, and inference are accepted as sound approaches to understanding, and they are used in synthesis for this assessment.

### ***Publication of Assessment on the World Wide Web***

To facilitate use of species assessments in the Species Conservation Project, they are being published on the Region 2 World Wide Web site (<http://www.fs.fed.us/r2/projects/scp/assessments/index.html>). Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. In addition, Web publication will facilitate revision of the assessments, which will be accomplished based on guidelines established by Region 2.

### ***Peer Review***

Assessments developed for the Species Conservation Project have been peer reviewed prior to their release on the Web. This assessment was reviewed through a process administered by the Society for Conservation Biology, which employed at least two recognized experts on this or related taxa. Peer review

was designed to improve the quality of communication and to increase the rigor of the assessment.

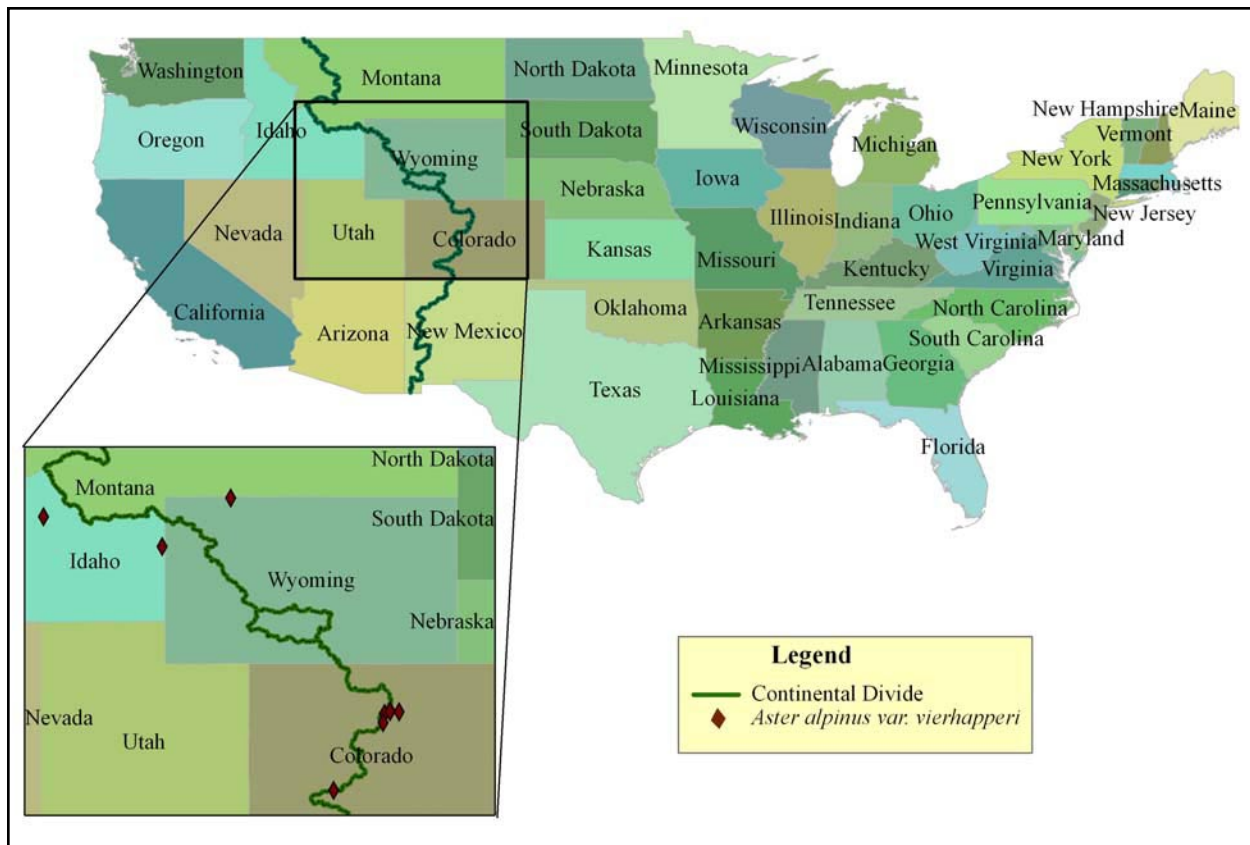
## **MANAGEMENT STATUS AND NATURAL HISTORY**

### ***Management Status***

*Aster alpinus* var. *vierhapperi* is native to North America and the middle Altai Mountains of central Asia, with occurrences in northwestern Canada, Alaska, and the Rocky Mountain West. Locations in Idaho, Wyoming, and Colorado (**Figure 1**) are considered disjunct from northern occurrences. In Region 2 (Colorado and Wyoming), five of the six documented occurrences are on National Forest System lands. Four occurrences are documented from National Forest Service lands in Idaho (Region 4). Only two of the Idaho locations are displayed in **Figure 1**, and those are generalized locations based on limited geographic information from specimens.

*Aster alpinus* var. *vierhapperi* is not federally listed or a candidate for listing under the Endangered Species Act, nor is the plant designated a sensitive species on any National Forest System lands (USDA Forest Service 2003b). The global heritage status rank for the taxon is G5T5 (secure - common, widespread, and abundant, although it may be rare in parts of its range, particularly on the periphery, typically with considerably more than 100 occurrences and more than 10,000 individuals). The national heritage status rank in the United States is NNR (nation conservation status not yet assessed). The taxon is considered critically imperiled (S1) in Ontario, Canada, where it is known from a single location near Hudson Bay (Brouillet personal communication 2004c, Semple personal communication 2004). It is reported as vulnerable to apparently secure (S3S4) in British Columbia (21 to 100 occurrences or between 3,000 and 10,000 individuals) and apparently secure to common, widespread, or abundant (S4S5) in the Yukon Territory. This taxon is not ranked/under review (SNR) in Alberta and the Northwest Territories (NatureServe Explorer 2006).

In Colorado, *Aster alpinus* var. *vierhapperi* is classified as S1 (critically imperiled in the state because of extreme rarity or because of some factor(s) making it especially vulnerable to extirpation from the state, typically five or fewer occurrences, or fewer than 1,000 remaining individuals). Occurrence 003\*CO on the Arapaho and Roosevelt National Forests in Colorado is included within an area that CNHP has designated as



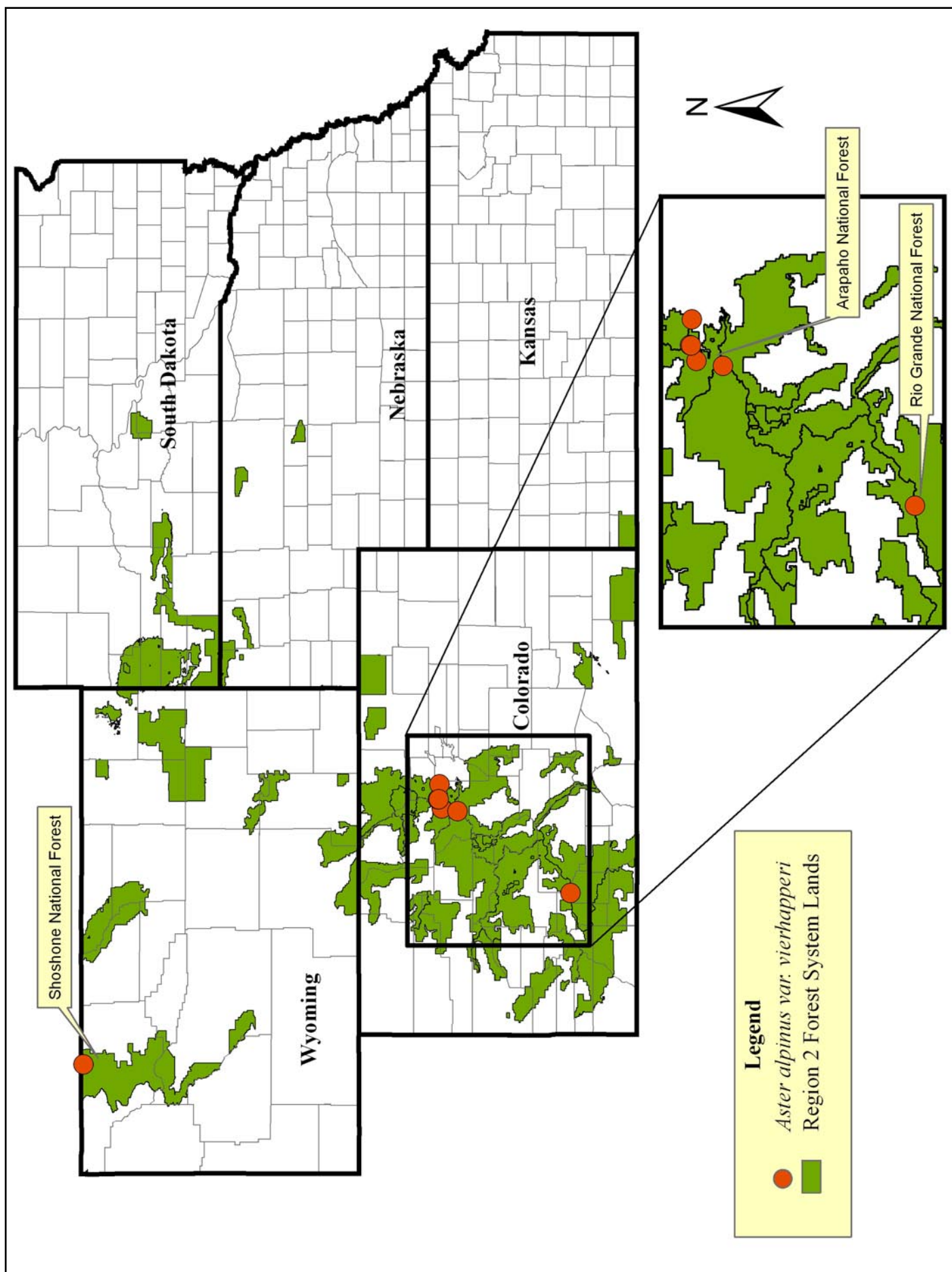
**Figure 1.** Distribution of *Aster alpinus* var. *vierhapperi* occurrences in the contiguous United States.

a potential conservation area. This designation confers no legal or regulatory protection on the species, but it does indicate its conservation value. Occurrences of *A. alpinus* var. *vierhapperi* in Wyoming and Idaho were recently brought to the attention of the USFS and WYNDD during the writing of this assessment. According to WYNDD, the new occurrence record of this taxon from a 1979 collection in Park County will result in an automatic S1S? rank for the taxon (as above S1S? indicates an inexact or uncertain rank but likely critically imperiled) (Heidel personal communication 2004). The Idaho Natural Heritage Program will review the status of the taxon in that state, and if the results of the review concur that the taxon occurs in Idaho, it will also be given a S1 designation (Cooke personal communication 2004). The Alaska Natural Heritage Program reports approximately 10 occurrences of this taxon across a wide area and designates it as imperiled (S2). It is likely that this designation will be downgraded to vulnerable (S3) after further floristic research is accomplished in the region (Lipkin personal communication 2004).

*Aster alpinus* (variety not indicated) is listed as occurring in Alaska in the Wrangell-St. Elias National

Park and Preserve. *Aster alpinus* var. *vierhapperi* is listed as occurring in Alaska in the Lake Clark National Park and Preserve and the Noatak National Preserve (University of California Davis 2004). This species/taxon is not known to occur in any of the national parks within the boundaries of Region 2.

Within Region 2, five of the six documented occurrences of *Aster alpinus* var. *vierhapperi* are located on National Forest System lands (**Figure 2**). Although it is not considered a sensitive taxon within Region 2, the National Forest Management Act and its rules require the USFS to sustain habitats that support healthy populations of existing plant and animal species on the national forests and grasslands. In Wyoming, management of the one known occurrence on National Forest System lands is based on the Shoshone National Forest Land and Resource Management Plan approved in 1986, as amended (USDA Forest Service 1986). Within Colorado, management of the four National Forest System lands occurrences is subject to the standards and guidelines of the Revised Rio Grande National Land and Resource Management Plan (USDA Forest Service 1996) and the 1997 Revised Land and Resource Management



**Figure 2.** Distribution of *Aster alpinus* var. *vierhapperi* occurrences within USDA Forest Service Region 2.

Plan for the Arapaho and Roosevelt National Forests and Pawnee National Grassland (USDA Forest Service 1997). The Golden Gate Canyon State Park does not have a management plan that specifically addresses *A. alpinus* var. *vierhapperi*.

Because *Aster alpinus* var. *vierhapperi* does not have sensitive species status in Region 2, project-specific National Environmental Policy Act compliance does not require evaluation of project alternatives with respect to this taxon. The final recommendation regarding inclusion of *A. alpinus* var. *vierhapperi* on the 2003 Region 2 sensitive species list was that “insufficient information” was available to support designation as sensitive (USDA Forest Service 2003b). The purpose of this assessment is to provide information to facilitate management decisions and to assist in re-evaluating the status of this variety (USDA Forest Service 2003a).

No specific management or conservation plan is in place for protection of this variety on National Forest System lands. Existing laws, regulations, management, and their enforcement may not adequately protect occurrences on National Forest System lands because no taxon-specific protective mechanisms are in place.

## ***Biology and Ecology***

### Classification and description

#### *Systematics and morphology*

*Aster alpinus* var. *vierhapperi* is a member of the Sunflower family (Asteraceae or Compositae), which is one of the largest families of plants in the world. This family is cosmopolitan in distribution and consists of approximately 1,160 genera and 19,085 species. Many members of this family are well adapted to temperate, montane, or dry regions. North American representatives include some 346 genera and 2,687 species (Zomlefer 1994). The largest genera worldwide include *Erigeron*, *Aster*, *Senecio*, and *Cirsium*.

The taxonomy of the Asteraceae, and for our purposes the Astereae tribe, is in a state of flux, primarily due to recent molecular and morphological analyses. Linnaeus originally described *Aster alpinus* in his Species Plantarum in 1753. Globally, the *A. alpinus* L. complex currently consists of 11 taxa, including seven varieties and four subspecies (IPNI 2004, W3TROPICOS 2004). Two taxa of *Aster* are currently recognized in North America, *A. tataricus* L. and *A. alpinus* var. *vierhapperi* (Brouillet 2004a, USDA

Natural Resources Conservation Service 2004). The typical variety, *A. alpinus* var. *alpinus*, is frequently used as a horticultural rock garden plant and is commonly found in nurseries throughout the world.

Aven Nelson first described *Aster alpinus* var. *vierhapperi* as *A. culminis* A. Nels in 1909. A revision of *Aster*, section *Alpigeni* by Onno in 1932 moved *Aster culminis* into the *A. alpinus* group. In 1980, the results of a cytological and morphological study of the genus *Aster* placed *A. alpinus* into the subgenus *Amellastrum*, members of which share similar habit, leaf characteristics, and involucre characteristics with *Erigeron* (Semple and Brouillet 1980, Nesom 1994). Nesom (1994) placed *Aster alpinus* in the section *Aster*, subsection *Alpigeni*, where *Aster alpinus* var. *vierhapperi* is the only new world representative. In 1996, the results of a cpDNA (chloroplast DNA) study (Xiang et al. 1996) proposed that the *A. alpinus* group be moved to the genus *Diplactis*. However, ribosomal DNA ITS (internal transcribed spacer) sequence data indicated that the species rightfully belongs to *Aster* as per Nesom (1994) and not *Diplactis* (Allen et al. 2001).

There are two synonyms associated with *Aster alpinus* var. *vierhapperi*, *A. alpinus* ssp. *vierhapperi* Onno and *Diplactis alpinus* ssp. *vierhapperi* (Onno) Semple. Twenty-three years after Onno revised the section of the genus, Cronquist classified the taxon under discussion as a variety, adopting the current accepted name of *A. alpinus* var. *vierhapperi* (Hitchcock et al. 1955, USDA Natural Resources Conservation Service 2004). **Table 1** summarizes the nomenclatural data of *A. alpinus* var. *vierhapperi*.

#### *History of species*

The earliest collection of *Aster alpinus* var. *vierhapperi* on record in Colorado was made by George Smith in 1871 south of Gray’s Peak in Clear Creek County (Smith #s.n. COLO). Tweedy documented an occurrence of *A. alpinus* var. *vierhapperi* in 1903, near Berthoud Pass, Colorado (Tweedy #5797 RM!). The Tweedy collection was designated the type specimen and described as *A. culminis* by Aven Nelson in 1909. The taxon remained undocumented in Colorado for over sixty years. The *A. alpinus* species complex underwent a revision in 1932 by Max Onno where *A. culminis* was reclassified as a subspecies of *A. alpinus* (Onno 1932). The taxon was rediscovered in a collection made by Betty Willard (Willard #686) in 1968, but the specimen remained unidentified until William Weber identified it in 1988 (Weber 1989). The most recent known

**Table 1.** Classification of *Aster alpinus* var. *vierhapperi* (Hitchcock et al. 1955, Nesom 1994, Brouillet 2004a).

*Aster alpinus* L. var. *vierhapperi* (Onno) Cronquist

**Family:** Asteraceae (Compositae)

**Tribe:** Astereae

**Genus:** *Aster*

**Section:** *Aster*

**Subsection:** *Alpigeni*

**Species:** *Aster alpinus* L.

**Infraspecific Taxon:** *Aster alpinus* var. *vierhapperi* (Onno) Cronquist

**Citation:** Linnaeus Species Plantarum 2:872. 1753. M. Onno Bibliotheca Botanica 26 (Heft 106): 25. 1932. A. Cronquist *Vascular Plants of the Pacific Northwest* 5: 76. 1955.

**Synonyms:** *Aster alpinus* L. subsp. *vierhapperi* Onno; *Aster americanus* Onno nom. Invalid; *Aster culminis* A. Nels. *Diplactis* (L) Semple *alpinus* subsp. *vierhapperi* (Onno) Semple

**Vernacular Name:** Alpine Aster, Vierhapper's aster

**Type:** *Aster culminis* A. Nels., New Man. Bot. Central Rocky Mts. 513. 1909. TYPE: U.S.A. Colorado. Grand Co.: Berthoud Pass, 12,000', Jul 1903, *Tweedy* #5797 (HT: RM!)

collection of *A. alpinus* var. *vierhapperi* occurred in 2001 in Golden Gate Canyon State Park.

The variety was first documented in Park County, Wyoming in 1979 (*Brouillet and Semple* #4432), but this was overlooked until recently. The taxon also occurs in Custer County, Idaho, where it was discovered as a misidentified *Aster* (*Moseley* #533). Three other locations in Idaho have been reported recently, two in Teton County and one in Fremont County (Region 4, Grand Targhee National Forest). However, the curator of the herbarium at Brigham Young University - Idaho (RICK) believes that only one of the three collections is truly *A. alpinus* var. *vierhapperi* (Baird personal communication 2004). These collections have not been verified for the Flora of North America (FNA) treatment by Luc Brouillet.

The historic global distribution of *Aster alpinus* var. *vierhapperi* is circumboreal in the Holarctic Kingdom (Hultén 1968). Its known distribution occurs in central Asia (Altai Mountains), the Canadian Province, Vancouverian Province, and the Rocky Mountain Province as defined by (Takhtajan 1986). In the strict sense, this is the only variety of the genus *Aster* native to North America (Nesom 1994, Brouillet 2004a). William Weber's recent review of the biogeographical origins of the southern Rocky Mountain flora has resulted in a hypothesis that the alpine flora was intact during the Tertiary period and in fact antedates the modern

Arctic flora. He believes there was a greater Oroboreal (high mountain origin) flora extending from the Altai mountains (middle Asia) across the North Pole by way of Greenland and then eventually this flora became fragmented through isolation of various mountain ranges in North America (Weber 2003). Thus, the alpine species found in the southern Rocky Mountain flora are relicts of an older Tertiary flora. Weber cites this variety as one of the elements supporting his conclusion (Weber 2003). Currently, *A. alpinus* var. *vierhapperi* is known to occur in Canada, Alaska, and the Altai Mountains. Distribution of this taxon in the southern end of its range in the United States is limited to two geographic areas within Colorado (Region 2), one location in Wyoming (Region 2), and possibly three areas in Idaho (Region 4).

#### *Morphological characteristics*

All members of the Asteraceae are unified by the presence of a head inflorescence (capitulum) subtended by numerous bracts (phyllaries or involucre). The head consists of usually several to many florets, some of which are disk flowers (tubular shaped corollas, located in the center of the head) and some of which are ray or ligulate flowers (strap shaped corollas, generally on the outside of the disk). Tremendous variation concerning the number, absence, presence, or combination of disk, ray, or ligulate florets is present within the family (Zomlefer 1994).

*Aster alpinus* var. *vierhapperi* is a rhizomatous, caespitose, perennial herb, 1 to 3 dm (4 to 12 inches) tall. The stems are shortly gray-pubescent, with wooly villous to densely wooly pubescence under the heads. The basal leaves are oblanceolate or obovate to spatulate, apically rounded or acute, and entire. The basal leaves can be up to 7 cm (2.7 inches) long. The cauline leaves are progressively reduced and become more or less linear distally. The heads are solitary, large, and rather showy. The disks are approximately 2 cm (0.8 inches) wide or more. The involucre is broadly hemispheric and herbaceous throughout or slightly chartaceous (papery texture, usually not green) at the base and about 1 cm (0.4 inches) high, with the bracts oblong-linear, loosely erect, and sub-equal in two to three series. Ray flowers are generally white (sometimes violet or lavender), reflexed, and shrunken, but they are persistent after flowering. Disk flowers are yellow. The involucre opens at maturity exposing the fruits. The fruits are widely spreading reddish brown achenes, 2 to 2.5 mm (0.08 inches) long and flattened with densely appressed-strigose hairs. The pappus of barbellate bristles is off-white or yellowish in color (Hitchcock et al. 1955, Brouillet 2004a). Two easily understood technical descriptions of this taxon can be found in the Vascular Plants of the Pacific Northwest (Hitchcock et al. 1955) and in the Flora of North America, Volumes 19, 20, and 21 (Brouillet 2004a). **Figure 3** is a photograph of *A. alpinus* var. *vierhapperi* inflorescences showing disk and ray flowers.

In the Altai Mountains of central Asia, there is apparently a form of this variety differing in trichome (hair) structure on the stems. In that form, the basal cells are striate, and in the American form the basal cells are papillose (Weber 1989, Weber 2003, Brouillet 2004a, Weber personal communication 2004). Corolla color varies across the range of this variety. Siberian plants tend to have purplish rays whereas in North American plants, rays are typically pinkish white to pink (Brouillet 2004a).

The genus *Aster* is typically confused with *Erigeron*. It generally differs in having leaf-like phyllaries with a chartaceous base. The phyllaries are more often imbricate than sub-equal and have longer narrower style branches than those found in *Erigeron*. Additionally, *Aster* species typically flower later in the year than members of *Erigeron* (Nesom 1994).

*Aster alpinus* var. *vierhapperi* is apparently easily identified in the field due to its dwarf stature, large solitary heads, and appressed-strigose pubescence on the involucre (Yeatts personal communication 2004). Brouillet (2004b) believes this taxon to be easily recognized by its rosette leaves; single heads with subequal, leaf-like phyllaries; and obconic, flattened, 2-nerved, puberulent, apically glandular fruits. Confusion in field identification is frequently related to distinguishing *Erigeron* from *Aster* as discussed above. *Aster alpinus* var. *vierhapperi* can be confused



**Figure 3.** *Aster alpinus* var. *vierhapperi* inflorescences showing disk and ray flowers. Photograph used with the permission of Loraine Yeatts (2001).

with alpine members of *Erigeron*. It is most frequently confused with *E. elatior*, which differs in having multi-cellular hairs with reddish cross-walls, as well as other characteristics separating the two genera given above. In addition, *A. alpinus* var. *vierhapperi* is often confused with *E. caespitosus* Nutt., *E. peregrinus* (Pursh) E.L. Green, and *E. hyperboreus* Greene among others (Brouillet 2004a). Careful determination of the correct genus as previously discussed can minimize these misidentifications.

## Distribution and abundance

Global distribution of *Aster alpinus* var. *vierhapperi* includes arctic and alpine regions extending from central Asia in the Altai Mountains, Siberia, and east across Alaska and Canada to Ontario and south to Colorado, Idaho, and Wyoming. Distribution of this variety on National Forest System lands is disjunct from its primary distribution in northern North America and Eurasia, exhibiting a discontinuous distribution across Colorado, Wyoming, and Idaho occupying suitable habitat in the high mountains often adjacent to the continental divide. CNHP reports five Element Occurrence Records (EORs) for *A. alpinus* var. *vierhapperi* located in Clear Creek, Gilpin, Grand, and Mineral counties. Four of the known occurrences are located on National Forest System lands within the Rio Grande and Arapaho and Roosevelt national forests, and one is located in the Golden Gate Canyon State Park (**Table 2, Figure 2**). All of the CNHP occurrences are represented by specimens verified by William A. Weber and deposited in several herbaria, including the Rocky Mountain Herbarium (RM), Kathryn Kalmbach Herbarium (KHD), and the University of Colorado Museum (COLO). This assessment will include discussion of all four reports of occurrences within Idaho. Three of these occurrences may be questionable. Nonetheless, it is in the best interest of conservation to include them until the Idaho Natural Heritage Program has verified the validity of these occurrences.

The Wyoming occurrence of *Aster alpinus* var. *vierhapperi* is a recent discovery. The collectors did not realize at the time of collection the importance of their find, and consequently they did not report it to WYNDD (Brouillet personal communication 2004c). It was overlooked until the FNA project (referenced earlier) initiated a treatment of the genus by Luc Brouillet, when it was rediscovered during the preparation of the *Aster* treatment. The specimen was collected in 1979 in Park County (Shoshone National Forest) and verified by Luc Brouillet and John Semple (Brouillet and Semple #4432). Herbarium specimens for this collection

are deposited at Université de Montréal (MT) and University of Waterloo (WAT). During the preparation of this assessment, the Wyoming occurrence was brought to the attention of WYNDD. The recent discoveries of locations in Idaho and Wyoming have partially filled the gap between a southern Canadian occurrence in Alberta and the southern Rocky Mountain locations in Colorado (Brouillet 2004b).

Abundance information from Region 2 is scarce or nonexistent for this variety, and the existing information is based upon a single casual field estimate. Given the lack of available data, an accurate estimation of ecological density in the statistical sense is not possible. Four of the five Colorado locations report no abundance data at all. Only one of the five occurrences (003\*CO) has been revisited, and abundance information was recorded on just one of those occasions. This occurrence consists of two suboccurrences, and in 1992 one of the suboccurrences was estimated to consist of approximately 200+ individuals. The other suboccurrence was not counted. The Golden Gate Canyon State Park occurrence is the most recently collected occurrence, but no abundance data were recorded. It is impossible to estimate accurately the number of individuals of *Aster alpinus* var. *vierhapperi* present in Colorado at this time. In Wyoming, no estimates of abundance were recorded. Nevertheless, based on the available element occurrence record and herbarium label data summarized in **Table 2**, it is estimated that, at the very least, 200 or more individuals make up the known abundance of this variety in Region 2.

## Population trend

No population trend studies have been conducted for *Aster alpinus* var. *vierhapperi* in Region 2 or elsewhere. Only one Region 2 occurrence (003\*CO) has been revisited, but census data were recorded during only one visit for one of the two suboccurrences. Colorado occurrences (001\*CO, 004\*CO, 002\*CO) have not been observed in at least twenty years. All that is known is that *A. alpinus* var. *vierhapperi* occurs in a patchy pattern, occupying residual or well-developed turf on alpine tundra and in open aspen forests. Due to the lack of data, no inferences can be made concerning the temporal pattern of abundance of this taxon at any spatial extent.

## Habitat

*Aster alpinus* var. *vierhapperi* is a plant of alpine and arctic regions. The Canadian and Alaskan

**Table 2.** Summary of abundance and habitat data for *Aster alpinus* var. *vierhapperi* taken from Colorado Natural Heritage Program (CNHP) element occurrence records (EORs), herbarium label data, and USGS 7.5 minute topographic maps (Colorado Natural Heritage Program 2004). N/A = Not Available. “Herbarium” indicates herbarium acronym where specimen is deposited (see glossary for herbarium information). \*\* = identification questionable

EOR and collection#	County	Date(s) observed	Area (ha)	Number of occurrences	Total number of plants	Land management location note (Herbarium)	Elevation (m)/ aspect	Substrate	Slope (%)	Vegetation cover (%)	Habitat characteristics and association
001*CO <i>Tweedy</i> #5797	Grand	1903	N/A	1?	N/A	USDA Forest Service (USFS) Region 2 Arapaho and Roosevelt National Forests. Berthoud Pass Quadrangle (COLO, RM)	3,352/ N/A	Granitic rocks	N/A	N/A	N/A
002*CO <i>Willard</i> #686	Mineral	1968	N/A	1?	N/A	USFS Region 2 Rio Grande National Forest. Spring Creek divide. (COLO)	3,681/ N/A	Tertiary aged intra-ash-flow quartz latitic lavas	N/A	N/A	N/A
003*CO <i>Weber</i> #18495 and #19187; <i>Yeatts</i> #3308	Gilpin	1992 1996	65	2	200+	USFS Region 2 Arapaho and Roosevelt National Forests. Kingston Peak (COLO, RM)	3,300-3,500/ N/A	Tertiary aged intra-ash-flow quartz latitic lavas	Level to gentle	Sparse	Alpine tundra. Sparsely developed turf, confined to residual patches of shallow turf, not found on the gravelly substrate typical of the site N/A
004*CO <i>Smith</i> s.n.	Clear Creek	1871	N/A	1?	N/A	USFS Region 2 Arapaho and Roosevelt National Forests. Below Gray’s Peak (COLO)	3,600/ N/A	Biotitic gneiss, schist, and migmatite	N/A	N/A	N/A
005*CO <i>Senser</i> s.n.; <i>GGC</i> #581 and #103; <i>Smookler</i> #237	Gilpin	2001	N/A	1?	N/A	Golden Gate Canyon State Park. Ralston Creek drainage (COLO, RM, KHD)	2,585/ S-facing	Granitic rocks	N/A	N/A	Montane forest. Locally scattered in clumps in dry sandy humic soil on south facing slope within an open aspen forest populated with low juniper N/A
001*WY <i>Brouillet</i> and <i>Sample</i> #4432	Park	1979	N/A	1?	N/A	USFS Region 2 Shoshone National Forest. Beartooth Pass (MT, WAT)	3,334/ N/A	Precambrian Gneiss	N/A	N/A	N/A

Table 2 (concluded).

EOB and collection#	County	Date(s) observed	Area (ha)	Number of occurrences	Total number of plants	Land management location note (Herbarium)	Elevation (m)/ aspect	Substrate	Slope (%)	Vegetation cover (%)	Habitat characteristics and association
001*ID <i>Moseley</i> #533	Custer	1984	N/A	1?	N/A	USFS Region 4 Challis National Forest. Lost River Range (RM)	3,017/ N/A	Deep, clay soil with a mantle of gravel	N/A	N/A	Alpine, moist meadow depression
002*ID <i>Wachs</i> #151; ** <i>Jensen s.n.</i> , #14	Teton	1982 1979	N/A	2?	N/A	USFS Region 4 Caribou-Targhee National Forest Big Hole Mountains (RICK)	N/A	N/A	N/A	N/A	Sub-alpine and alpine meadow
003* ID ** <i>Lindsay</i> #1784	Fremont	1972	N/A	N/A	N/A	USFS Region 4 Caribou-Targhee National Forest Sawtell Peak summit (RICK)	N/A	N/A	N/A	N/A	Alpine meadow

populations can be found in a variety of habitats, including open to semi-shaded exposures, mesic to dry areas in rocky, gravelly, silty, or granitic substrates. *Aster alpinus* var. *vierhapperi* can occur on *Artemisia* (sagebrush) steppes, cold prairies, edges of riparian boreal forests, or sandy ridges in muskegs. Some other habitat types in the far north, in which it has been documented, include gravelly or eroding river-banks and flats, bluffs, talus slopes, and cliffs (Brouillet 2004a). Apparently, within its primary range this variety shows a broad range of habitat types. This does not appear to be the case in the southern end of its range in the United States. All but one of the known southern populations are located at high elevations, typically occupying the alpine tundra on the slopes and saddles of the high mountains. Many occurrences are located along the continental divide. One occurrence (005\*CO) was documented in an aspen forest in the montane zone. **Table 2** summarizes EOR and herbarium label data, including vegetation, elevation, substrate, slope, and aspect. **Figure 4** and **Figure 5** show the habitat of *A. alpinus* var. *vierhapperi*.

In Region 2, *Aster alpinus* var. *vierhapperi* occurs within the Southern Rocky Mountain Steppe-Open Woodland-Coniferous Forest-Alpine Meadow Province. It occurs or potentially occurs in several sections within this province, including the South-Central Highlands, Northern-Central Highlands-Rocky Mountain, and the Northern Parks and Ranges. This taxon also has documented occurrences or could occur in several sections of the Middle Rocky Mountain Steppe-Coniferous Forest-Alpine Meadow Province, generally located within Region 4 and Region 1 (McNab and Avers 1994).

Very little, if any, site information was recorded at the most of the occurrences. No information concerning aspect was reported for any of the alpine occurrences of *Aster alpinus* var. *vierhapperi*, but was recorded for the montane location (005\*CO). Elevation was the only physical characteristic reported for all of the occurrences. According to the available occurrence data, elevations range from 3,300 m to 3,700 m (10,800 to 12,200 ft.; see **Table 2** for individual site elevations). Landscape and topographic position was noted at two of the occurrences (003\*CO, 005\*CO) and soil characteristics were recorded at occurrence 005\*CO and on the Region 4 specimen (*Moseley* #553 RM). Geologic substrates associated with this taxon within Region 2 include Precambrian and Cambrian granites, gneisses, and schists or Tertiary volcanics (**Table 2**). Due to a lack of information, it is not possible to draw conclusions or to identify any specific

geological site characteristics indicative of *A. alpinus* var. *vierhapperi* habitat.

Alpine communities vary according to aspect, substrate, dominant species, and moisture regime, and they do not necessarily form distinct, separate associations. Indeed, the typical norm is a complex mosaic of communities with a range of elevation, aspect, soil stability, and moisture regimes (Billings 1988, Knight 1994). In 2001, the CNHP published the viability specifications for the southern Rocky Mountain ecosystems (Rondeau 2001). Four alpine communities were described in the document; these are the Alpine Substrate/Ice Field, Alpine Tundra Dry Meadow, Alpine Tundra Fellfield, and Alpine Dwarf Shrubland. There are not enough available habitat data for *Aster alpinus* var. *vierhapperi* to place this taxon definitively in a specific alpine ecosystem as defined by Rondeau. The mosaic nature of the alpine ecosystem, in general, is such that all four of Rondeau's communities can occur within a relatively small area. The fellfield community is often embedded within the dry tundra meadow. Likewise, ice fields and dwarf shrublands can be present within the dry tundra meadow mosaic. The current limited information appears to support the occurrence of *A. alpinus* var. *vierhapperi* within one of Rondeau's four described alpine ecosystems, the Alpine Tundra Dry Meadow. This community typically occurs between 3,050 m and 4,250 m (10,000 to 14,000 ft.) in elevation on gentle to moderate slopes in flat ridges, valleys, and basins where soil is relatively stable and the water supply is more or less constant. The Alpine Tundra Dry Meadow is co-dominated, for the most part, by various species of *Carex* and *Geum rossii* var. *turbinatum* (Rondeau 2001).

The alpine fellfield can be described as an alpine desert or high elevation rock garden. Fellfields are typically dry and are often found on sites tipped into the wind. Water drains rapidly from fellfield patches, and solar radiation can be intense (Billings 1988, Emerick and Mutel 1992, Rondeau 2001). *Aster alpinus* var. *vierhapperi* was observed growing within a dry tundra meadow interspersed with fellfield, but it was not present in the typical dry fellfield patches (*Yeatts* #3308, *Weber* #18495). None of the available information for the Region 2 documents occurrences within fellfield patches, late snowmelt areas, or alpine dwarf shrubland. It is possible, however, that this variety could be found in any of the alpine ecosystems. Nevertheless, based upon the available herbarium label data, it is less likely to occur in the drier, wind-exposed fellfield patches. **Figure 4** illustrates the taxon associated with the developed alpine turf community and not the



**Figure 4.** Habitat of *Aster alpinus* var. *vierhapperi*, illustrating presence in turf community surrounded by fellfield patches. Photograph used with the permission of Loraine Yeatts (2001).



**Figure 5.** Typical alpine mosaic habitat for *Aster alpinus* var. *vierhapperi*. Photograph used with the permission of Loraine Yeatts (2001).

surrounding fellfield patches. **Table 3** lists associated species noted to occur with *A. alpinus* var. *vierhapperi*.

One of the many interesting things about alpine habitats is the variation occurring within the alpine environment. It has been shown that the alpine environment varies greatly with topographic position (e.g., ridgelines, depressions, lee versus windward slopes) (Billings 1973). Aspect can greatly affect

temperature, moisture, and exposure, particularly in the alpine (Billings 1973, Billings 1974, Thilenius 1975, Billings 1988, Knight 1994). It is not known which or how these microhabitat factors influence the distribution of *Aster alpinus* var. *vierhapperi*. Nevertheless, in Region 2, herbarium label data for this variety consistently indicate a preference for alpine turf, which requires some degree of soil development. Soil development in the alpine generally requires an

**Table 3.** Species noted to occur with *Aster alpinus* var. *vierhapperi*. List generated from herbarium label data in both the alpine and montane habitat.

Scientific Name	Vernacular Name	Scientific Name	Vernacular Name
<i>Allium geayeri</i>	Geyer's onion	<i>Geranium caespitosum</i> ssp. <i>atropurpureum</i>	Magenta geranium
<i>Anemone multifida</i>	Red windflower	<i>Koeleria macrantha</i>	Prairie junegrass
<i>Besseyia plantaginea</i>	White River coraldrops	<i>Mertensia lanceolata</i>	Prairie bluebells
<i>Campanula rotundifolia</i>	Bluebell, bellflower	<i>Packera cana</i>	Woolly groundsel
<i>Carex elynoides</i>	Blackroot sedge	<i>Packera werneriiifolia</i>	Hoary groundsel
<i>Castilleja puberula</i>	Shortflower Indian paintbrush	<i>Poa alpina</i>	Alpine bluegrass
<i>Eremogone fendleri</i>	Fendler's sandwort	<i>Potentilla diversifolia</i>	Cinquefoil
<i>Eritrichum aretioides</i>	Arctic alpine forget-me-not	<i>Sibbaldia procumbens</i>	Creeping sibbaldia
<i>Festuca brachyphylla</i> ssp. <i>coloradensis</i>	Colorado fescue	<i>Solidago multiradiata</i>	Rocky Mountain goldenrod
<i>Festuca ovina</i>	Sheep fescue	<i>Tetraneuris brevifolia</i>	Caespitose four-nerve daisy
<i>Frasera speciosa</i>	Elkweed	<i>Trisetum spicatum</i>	Spike trisetum

exposure that is less subject to erosion and desiccation and has a consistent water source throughout the growing season. These conditions are not met in fellfield patches or in ice fields because the soils are typically immature and lack a consistent water supply; the former are often completely desiccated, and the latter frequently never melt or if they do it is for only a few weeks (Rondeau 2001). The available label data for *A. alpinus* var. *vierhapperi* noted it being confined to residual patches of shallow or sparsely developed turf (Weber #18495, Yeatts #3308). In Idaho, *A. alpinus* var. *vierhapperi* was documented to occur in a moist meadow depression with deep, clay soil and a mantle of gravel at the surface (Moseley #533 RM).

One of the locations in **Table 2** appears to be aberrant. This occurrence (005\*CO) is located in an open, moist, aspen-mixed coniferous montane forest. This location is unusual, considering the range-wide habitat of this taxon. In the far north, it has been documented in montane forests, sagebrush steppes, and cold prairies. Even the driest of these areas are still relatively cool, and all these areas are characterized by relatively deep, well-developed soils. The montane site in Colorado is situated in Golden Gate Canyon State Park, on a south-facing slope at 2,585 m (8,500 ft.) in elevation where temperatures are relatively warm compared to the cooler alpine habitat with which the taxon is generally associated. The montane association apparently represents a peripheral habitat type for this variety in the southern Rocky Mountains. During the preparation of the FNA treatment of *Aster*, Brouillet believed that this report may have been based upon misidentification. However, the collections (Senser s.n.; GGC #581 and #103; Smookler #237) were verified by

Hartman at RM and eventually examined and verified for the FNA treatment by Brouillet (MT) (Brouillet personal communication 2004c). This occurrence noted plants of *A. alpinus* var. *vierhapperi* locally scattered in clumps, in dry, sandy, humus rich soil. The dominant tree species reported at the site was *Populus tremuloides* (quaking aspen). Associated trees included *Pseudotsuga menziesii* (Douglas-fir), *Pinus ponderosa* (ponderosa pine), and *P. contorta* var. *latifolia* (lodgepole pine).

Potential habitat exists throughout the higher elevations of the southern Rocky Mountains, particularly in those areas close to and surrounding the continental divide. The continental divide may have provided a corridor of suitable alpine habitat for *Aster alpinus* var. *vierhapperi* to migrate along south from its primary range. The best habitat for locating additional occurrences would likely be along the alpine areas surrounding the continental divide. Potential habitat is present in Colorado on National Forest System lands in the San Juan, Rio Grande, Gunnison, Arapaho, and Roosevelt national forests, and possibly in the White River and Routt national forests. In Wyoming, potential habitat for this taxon exists in the Shoshone National Forest and possibly the Medicine Bow National Forest.

## Reproductive biology and autecology

### Autecology

An extensive literature search resulted in no empirical data describing ecological strategies for *Aster alpinus* var. *vierhapperi*. Grime (1979) developed a system of classifying plant strategies based on three basic stress responses. He termed these responses

competitor, stress-tolerant, and ruderal. Life history patterns have also been described as *r*- and *K*-selected, where *r*-selected species typically allocate more resources to reproduction, and *K*-selected species allocate more resources to survival. Grime's system should be viewed as a continuum between the two resource allocation strategies (MacArthur and Wilson 1967). Despite the lack of specific data describing the autecology of *A. alpinus* var. *vierhapperi*, much has been written about the adaptations of alpine plants in general. While no generalizations can be made concerning *A. alpinus* var. *vierhapperi* specifically, the harshness of the alpine habitat presents the similar challenges to all vascular plants.

Alpine plants, including *Aster alpinus* var. *vierhapperi*, are typically dwarfed and perennial. Most, but not all, alpine plants have relatively large underground root systems. *Aster alpinus* var. *vierhapperi* tends to be slightly woody at the base, and new shoots often arise from the base with rhizomes below the ground (Brouillet personal communication 2004c, Semple personal communication 2004). This taxon can be described as a dwarfed hemicryptophyte with thick fleshy rhizomes, often associated with species well adapted to surviving stressful environments as the perennating bud is protected during the harsh winter and short growing season (Grime 1979, Barbour et al. 1987). Nothing is known about the physiology of this taxon other than the location of its photosynthate storage system in the root crown (Hitchcock et al. 1955, Brouillet 2004a).

By far the most important adaptations to harsh alpine habitats are the responses to the short growing season and low temperatures (Billings 1974). Alpine plants generally survive the short growing season by growing rapidly. Rapid growth in an alpine environment is primarily due to a plant's ability to undergo physiological processes at low temperatures (Billings 1974). Low temperatures are overcome through a diminutive stature; the air temperature close to the ground may be relatively warmer than the air temperature 1 m above the ground. In addition, the physiognomy of the plant can create a phytomicroclimate where the temperature within the confines of the plant itself may be several degrees warmer than the surrounding environment. Phytomicroclimate can be affected by the degree of vestiture (hair) on a given plant species. Those with more hair or heavy cutinization (waxy coating) have an adaptive advantage in drought or low temperature conditions. *Aster alpinus* var. *vierhapperi* possesses more or less densely villous and/or appressed-strigose hairs on the stems, leaves,

and involucre, and these insulate the plant from cold, water loss, and damaging solar radiation (Billings 1974, Thilenius 1975). Another strategy for surviving low temperatures is the presence of relatively high osmotic concentrations of plant fluids that may prevent the plant from freezing during nocturnal temperature drops (Thilenius 1975). It is not known whether this applies to *A. alpinus* var. *vierhapperi*.

In reality, species can take on any combination of characteristics of ruderals, competitors, and stress-tolerant responses. There is not enough data to classify *Aster alpinus* var. *vierhapperi* definitively. Given the harsh alpine environment, this taxon is more likely stress-tolerant than either a competitor or a ruderal, allocating its resources to survival (*K*-selected) rather than reproduction (MacArthur and Wilson 1967, Grime 1979). Nevertheless, this taxon may exhibit good competitor traits in its ability to establish itself in the turf community and is apparently not restricted to sparsely vegetated areas suggesting a poor competitive ability. In addition, on at least one occasion in Region 2, this variety was successful in establishing an occurrence in the resource-rich montane aspen forest. The life history systems described here are not a definitive classification of ecological strategy; natural variability reminds us that many combinations can occur. Grime (1979) and MacArthur and Wilson's (1967) systems are useful conceptual models for classifying autecological strategies of individual species and for determining where an individual species can be placed in the broader picture.

### Reproduction

It is not known if this taxon flowers consistently year after year, how long fruits remain on the plant, or what the annual production of seeds is. *Aster alpinus* var. *vierhapperi* can reproduce vegetatively by growth and development of the perennating bud. It is monoecious, reproducing sexually by seed. The inflorescence is a solitary head consisting of 20 to 95 pink, white, lavender, or purple ray flowers 1.0 to 1.7(+) cm (0.4 to 0.7 in) long surrounding 50 to 100 yellow disk florets. *Aster alpinus* var. *vierhapperi* flowers from June through July, with undispersed fruits present at least through August (Weber #19187 COLO) (Brouillet 2004a). All of the white to pink-purple rayed asters with a base chromosome number of  $x = 9$  in the Eurasian *Aster* genus bloom earlier than native North American species in other similar aster genera (Brouillet 2004a, Semple personal communication 2004). In western Canada, blooming peaks for *A. alpinus* var. *vierhapperi* in July. In almost all alpine plants, flower primordia

are formed at least one year before flowering. These preformed flower buds insure that there is no delay in anthesis; flowering can occur from 10 to 20 days after snowmelt (Billings 1974). It is not known if this variety forms flower primordia.

No formal investigations have been developed to characterize the pollination mechanisms for this taxon. In the Asteraceae and in most alpine habitats, entomophily (insect pollination) is common. The flowers are presented in heads that open in sequence and offer little pollinator rewards. This lack of nectar per flower is compensated for by the long flowering period, which allows the heads to remain attractive and receptive for several weeks (Berry and Calvo 1989). The disk flowers present pollen by the early maturation of the anthers within the corolla followed by the subsequent pushing of the pollen, like a plunger, out of the corolla by the styles as the stigma lengthens (Zomlefer 1994). Cases of anemophily (wind pollination) have been observed in some composites at higher elevations, but these taxa possess a distinct morphology adapted to wind pollination, including reduced ray flowers, hanging capitula, and various pollen characteristics (Berry and Calvo 1989). *Aster alpinus* var. *vierhapperi* is characterized by large, solitary, showy flower heads, indicating that this variety is most likely insect-pollinated. Specific pollinators are not known, but typical alpine and Asteraceae pollinators include flies, bees, butterflies, and moths (Billings 1974, Leppik 1977). Effective pollination depends upon timing of anthesis, reproductive maturity of the individual flowers, plant density, and fluctuations in pollinator activity (annually and seasonally).

No information is available about the physiology of germination or establishment of seedlings for *Aster alpinus* var. *vierhapperi*. Moreover, no experimental data exist concerning the fertility or viability of the seeds. In general, Billings (1974) suggests seed germination and seedling establishment in the alpine environment are occasional. He concluded that alpine seed germination is under environmental control and the optimal combination of suitable temperature and moisture conditions may only occur occasionally. Seedling growth in the alpine is slow, with most production going into establishing a root system to ensure a carbohydrate bank to survive the harsh conditions. Several years may pass before a young plant is firmly established (Billings 1974). According to Grime (1979), a persistent seed bank is one in which at least some of the seeds are at least one year old. Billings (1974) observed that the seeds of alpine plants are produced late in the year and do not germinate until the following year, if then.

Additionally, Kaye (1997) determined that some alpine species require one or several treatments (e.g., cold, scarification, light) before germination can take place. He also found that some species did not respond to any treatment and the seeds remained dormant. We can only assume *A. alpinus* var. *vierhapperi* produces viable seed to some extent. Neither seedlings nor indication of recruitment have been observed. This is not to say that recruitment is not occurring; rather, none of the known occurrences have been monitored to determine if recruitment is happening.

No investigations into dispersal mechanisms have been accomplished for this taxon. The achenes of this variety possess a pappus of barbellate bristles, which indicates a possible wind dispersal agent (Zomlefer 1994, Brouillet 2004a). In addition, the seeds could be washed down slope by heavy rains or snow-melt runoff. Dispersal in the alpine may be affected by topography, regional climate, wind patterns, or precipitation.

There are currently no known examples of hybridization between *Aster alpinus* var. *vierhapperi* and any other species of *Aster* or members of the Astereae tribe. Nevertheless, hybridization has been observed between the old world species *A. amellus* and *A. alpinus* (Nesom 1994). There have been no reports of hybridization events occurring between old world *Aster* species and other genera such as *Erigeron*. If there were closely related relatives of *A. alpinus* var. *vierhapperi* in close proximity to the Region 2 occurrences, then hybridization might occur.

Asters are normally outcrossing, setting limited or no seed if not cross-pollinated. The diploid chromosome number of *Aster alpinus* var. *vierhapperi* is  $2n = 18$  (Brouillet 2004a). It is not possible to characterize the breeding system of *A. alpinus* var. *vierhapperi* definitively. There have been no empirical studies to show if *A. alpinus* var. *vierhapperi* is either self-compatible, apomictic, or an obligate outcrosser. It has been suggested within some families, including the Asteraceae, that some plants may exhibit spontaneous pseudo-compatibility (occasional self-fertilization). If these plants continue to self-fertilize, then inbreeding depression may result. However, it is thought that this path to obligate self-fertilization is uncommon and those individual plants that occasionally self-fertilize should be considered part of an outbreeding species (Mulcahy 1984). If *A. alpinus* var. *vierhapperi* were self-fertilizing, then a mechanism to overcome a lack of pollinators would exist. This would give this variety a reproductive advantage in the short term if pollination vectors are absent. On the other hand, in the long term,

selfing may promote homozygosity and possibly reduce fitness and the taxon's ability to adapt to changing environmental conditions (inbreeding depression) (Menges 1991, Weller 1994). In all probability, *A. alpinus* var. *vierhapperi* is an outcrosser; if so, then it would also have a long-term reproductive advantage by maintaining higher heterozygosity. In the short term, any loss of pollination vectors could theoretically reduce seed set (Weller 1994).

The relationship between rarity and genetic variation is a subject of increasing interest, and the past notion that rare species have a low level of genetic variation has been questioned (Linhart and Premoli 1993, Gitzendanner and Soltis 2000). There is no doubt that low genetic diversity does affect the ability of some rare plants to reproduce and survive (Fenster and Dudash 1994, Weller 1994). Genetic factors such as inbreeding depression and outbreeding depression should be considered in analyzing the genetic fitness of a species. *Aster alpinus* var. *vierhapperi* is in all likelihood an outcrossing species, which may facilitate the risk of outbreeding depression. In the unlikely event that this variety were to hybridize with the horticultural variety, *A. alpinus* var. *alpinus*, then it is possible that the introduction of these genes could reduce fitness by changing the ability of the variety to adapt to the locally harsh alpine environment or to future changes in the environment (Fischer and Matthies 1997). There is no evidence that *A. alpinus* var. *vierhapperi* readily undergoes natural hybridization. Given the lack of evidence and understanding, the authors of this report can make no inferences concerning genetic issues possibly associated with *A. alpinus* var. *vierhapperi*.

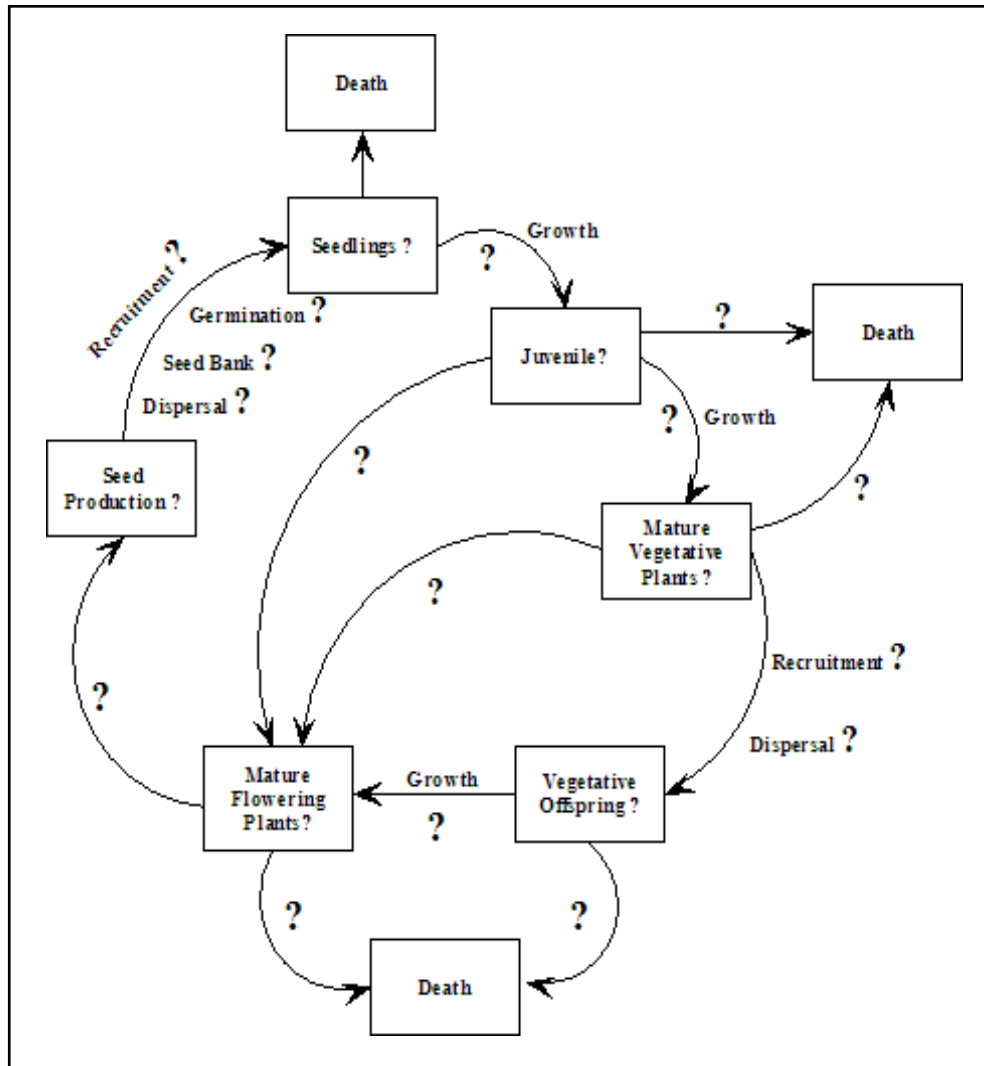
Phenotypic plasticity is defined as marked variation in the phenotype as a result of environmental influences on the genotype during development (Lincoln et al. 1982). There is no empirical evidence to suggest that the presence of ecotypes in *Aster alpinus* var. *vierhapperi*. It is interesting to note that the montane occurrence for this variety (005\*CO) presented a different form, atypical of the commonly seen dwarf habit. The montane specimen was approximately 25 cm (9.9 inches) in height, whereas the alpine specimens from the remaining Region 2 alpine occurrences averaged 10.0 cm (4 inches) or less in height. One specimen showing a taller appearance does not prove the presence of ecotypes. However, the possibility does exist that this taxon has the ability to adjust its morphology, perhaps in response to the need to improve its competitive ability in the generally taller vegetation found in the montane habitat, specimens from the far northern occurrences. An investigation using transplant

experiments would perhaps answer the question of phenotypic plasticity in *A. alpinus* var. *vierhapperi*.

Current literature indicates that relationships commonly exist between most higher plants and mycorrhizal fungi (Barbour et al. 1987). These relationships are poorly understood, and this is a growing area of scientific study. It is not surprising that there are no documented or observed mycorrhizal associations for *Aster alpinus* var. *vierhapperi*. Mycorrhizal relationships have been documented in the dry meadow alpine community and are important for fixing both nitrogen and phosphorus (Theodose and Bowman 1997). Mycorrhizae have been documented to occur in calcareous substrates, in fellfield cushion plant communities of the alpine of Wyoming and Montana (Lesica and Antibus 1986). Additionally, a study in Europe observed a 50 to 100 percent infection of dark septate hyphae of vesicular-arbuscular endomycorrhizae on the Eurasian *A. alpinus* var. *alpinus* (Read and Haselwandter 1981). Conversely, there is literature indicating a detrimental effect of mycorrhizae on rare plants. Hartnett and Wilson (1999) reported in a study that reduced mycorrhizae with fungicides, a consistent increasing trend among the rarer forb species (including heath aster *A. ericoides*) with their mean cover greater in fungicide-treated plots relative to controls. This study was conducted in a tallgrass prairie community where nitrogen is more readily available in the soils through increased decomposition of organic matter. In contrast, alpine environments are harsh and have limited nutrient resources. Vesicular-arbuscular endomycorrhizae are known to facilitate nutrient uptake in harsh environments (Grime 1979, Lesica and Antibus 1986). It is probable that vesicular-arbuscular mycorrhizal root infection is present in *A. alpinus* var. *vierhapperi* occurrences. Regardless of the lack of information concerning any specific mycorrhizal association that *A. alpinus* var. *vierhapperi* may have, this species may ultimately benefit from the mycorrhizal relationships that other members of the habitat may contribute to the substrate.

## Demography

The life history of *Aster alpinus* var. *vierhapperi* remains uninvestigated at this time. Observations by field botanists note populations were flowering and fruiting, indicating the occurrences were reproducing. However, no observations were recorded concerning the presence of seedlings. A simple life cycle diagram is presented in **Figure 6**. Question marks reflect a lack of understanding of the mechanisms between stages. It is not known if immature stages exist. If there is a juvenile



**Figure 6.** Generalized life cycle diagram of *Aster alpinus* var. *vierhapperi*. Question marks indicate uncertainty during a particular stage.

stage, it is unknown if juveniles must attain a certain size or stage before becoming reproductive, nor is it known if reproductive adults revert to a vegetative state. Seed bank dynamics (i.e., recruitment rates, seed longevity, abundance) are unknown but are represented in the diagram by a question mark between seed bank and seed. No information is available on germination rate or seedling survival, depicted in the diagram by a question mark between seed and seedling. *Aster alpinus* var. *vierhapperi* is a rhizomatous perennial; consequently, new individuals may become established from sprouts of underground rhizomes that have separated from the parent plant. It is not known how long an established vegetative offspring must grow before it attains reproductive age, either sexual or vegetative.

A population viability analysis is a rigorous quantitative analysis using demographic data to predict

the future status of a given species. A literature search for Population Viability Analysis (PVA) models for this species was performed. The minimum viable population (MVP) or the minimum population size necessary to have an acceptably low extinction probability can provide useful information for management purposes. It has been suggested that demography is of more immediate importance than genetics in determining the MVP for a plant species (Landes 1988, Menges 1991). Menges (1991) suggests that if a plant population is able to buffer environmental stochasticity, then the population will be sufficient to protect the genetic integrity of plant populations. No PVA has been completed for this taxon, and no MVP has been determined for *Aster alpinus* var. *vierhapperi* at this time.

Information concerning the demographic spatial characteristics for this taxon is limited. Only

one of all known occurrences in Region 2 has an estimated abundance, and no genetic data exist. A source population is generally a large or overcrowded population patch that cannot support immigration from neighboring populations, but from which individuals can disperse to other population patches or create new population patches. A sink population is a small population that requires immigration in order to sustain itself. There is not enough quantifiable abundance data or genetic data to identify sources and sinks of *Aster alpinus* var. *vierhapperi* populations. The authors refer to the distribution and abundance discussion above for a summary of what is known about the geographic distribution and abundance of *A. alpinus* var. *vierhapperi*.

Few factors limiting the population growth of *Aster alpinus* var. *vierhapperi* have been identified. Possible limiting factors include low germination rate, low seedling survivorship, and the inability of *A. alpinus* var. *vierhapperi* to disperse, particularly in the alpine. There are no identified specific mutualisms including mycorrhizal partners, pollinators, or dispersers. However, no investigations have been conducted concerning these mutualisms. This taxon is most likely an outcrosser; as such, this breeding system may buffer against the loss of heterozygosity, but it may be affected in the short term by dependence upon pollination mechanisms or other mutualisms not identified at this time. Currently, no empirical data exist examining other factors such as seed predation, competition, habitat destruction or fragmentation, or any other factor limiting population growth.

Alpine areas are more or less stable areas, albeit harsh. In the absence of anthropogenic-related activities, these habitats tend to remain stable (Thilenius 1975, Spence 1985). Alpine succession may play a role in creating habitat for this variety. Nevertheless, there is not enough known about the habitat, autecology, reproduction, or population dynamics to determine a primary cause for the rarity of this taxon.

#### Community ecology

*Aster alpinus* var. *vierhapperi* is generally located in inaccessible areas. The topographic locations of this variety provide a degree of isolation from interactions with invasive species. Possible invasive species interactions with *A. alpinus* var. *vierhapperi* are more likely to occur in the montane habitat, especially if a disturbance such as fire were to occur. No invasive species have been reported near the known occurrences. It is unknown if interactions with

native species have any effect on the distribution or abundance of *A. alpinus* var. *vierhapperi*. Interactions between species along an elevational gradient may affect alpine plant distribution. A study done in the alpine areas of the French Alps illustrated that species from lower elevations can move up the gradient. Neighboring plants may provide an insulating cover of the substrate that may increase the temperature around adjacent individuals. The study also indicates that competition from other species at lower elevations (where productivity is higher) prevents species from moving down the gradient (Choler et al. 2001).

The influence of habitat on community structure in the alpine and the montane has been studied at length (Billings 1988, Peet 1988). In montane areas, stand development depends for the most part upon some sort of disturbance regime, such as fire or beetle infestations. Gaps or openings in the montane forest can occur through windthrow, disease, or some unknown factor. *Aster alpinus* var. *vierhapperi* has one documented occurrence in an open montane forest. Disturbance has apparently played some role in creating this community structure in which *A. alpinus* var. *vierhapperi* was able to establish an occurrence.

There are no studies investigating parasites or diseases that may affect *Aster alpinus* var. *vierhapperi*, nor have there been any investigations of symbiotic or mutualistic interactions. Entomophily is an important symbiotic relationship for most flowering plants. *Aster alpinus* var. *vierhapperi* most likely depends upon insects to effect pollination. Specific information concerning the interaction between *A. alpinus* var. *vierhapperi* and insects is not known. Refer to the discussion on reproduction for what is known about entomophily and *A. alpinus* var. *vierhapperi*.

An envirogram is a useful tool for evaluating the relationship between the environment and a single species. It traces the environmental factors that affect a species from the most indirect (distal) interactions to factors that have a direct (proximal) effect (Andrewartha and Birch 1984). Traditionally, the envirogram is most often applied to animal/environment interactions. An example of an envirogram constructed for the *Pinus lambertiana* Douglas (sugar pine) showed the same principals used to construct an envirogram for animals could be equally applied to plants (Taylor 2000). The envirogram is a series of webs that converge upon a centrum. The centrum consists of the basic components of the environment that cause an increase, decrease, or no change in the expectation of fecundity and survivorship of a species. It is the most proximal level

of an envirogram that directly affects the target species (Andrewartha and Birch 1984). For plants, the centra consist of resources (i.e., light, soil moisture, nutrients), reproduction (i.e., flowering/fruitle, growth and development, seedling establishment), and malentities (i.e., human interactions, extreme weather, herbivory).

The envirogram is constructed as a modified dendrogram, with the centrum placed at the most proximal level to the species. From each of the centrum components, a web is constructed distally, illustrating factors that affect the centrum component, termed Web 1. Web 2 consists of factors that affect Web 1, Web 3 consists of factors that affect Web 2, and so on. One of the primary functions of an envirogram is to identify areas of research and to propose hypotheses (Andrewartha and Birch 1984). As with all analytical tools, the best envirogram is based upon a complete data set.

An envirogram was constructed for *Aster alpinus* var. *vierhapperi*, despite the lack of ecological and environmental data. Entries with a question mark denote areas in need of further research such as pollination mechanisms, herbivory, flowering/fruitle, the effect of disturbance, and dispersal vectors. **Figure 7**, **Figure 8**, and **Figure 9** provide a preliminary envirogram for *A. alpinus* var. *vierhapperi*. Web 4 levels and above (Web *n*) generally identify areas beyond the ecological and biological scope of the taxon. To aid in viewing, each centrum is color-coded. The resources centrum is green, the reproduction centrum is yellow, and the malentities centrum is blue.

The resources centrum for *Aster alpinus* var. *vierhapperi* (**Figure 7**) is made up of three proximal factors: soil moisture, light, and nutrients. Soil moisture is affected by precipitation, soil porosity (permeability), soil water retention, and runoff. Cloud seeding is an anthropogenic tool used to increase precipitation in the alpine areas where *A. alpinus* var. *vierhapperi* occurs. Light can be affected by community structure, geology, or topography, and the nutrient centrum is affected by such factors as substrate parent material and the addition of organic materials. The reproduction centrum consists of factors affecting flowering and fruitle (pollination, weather, dispersal), seedling establishment (possible safe sites, substrate, protection), and growth and development (weather, light, substrate). The malentities centrum identifies factors that may negatively affect *A. alpinus* var. *vierhapperi*, like extreme weather conditions, herbivory, competition, recreation, and pollution. Drought or unusually cold weather during the flowering and fruitle season can

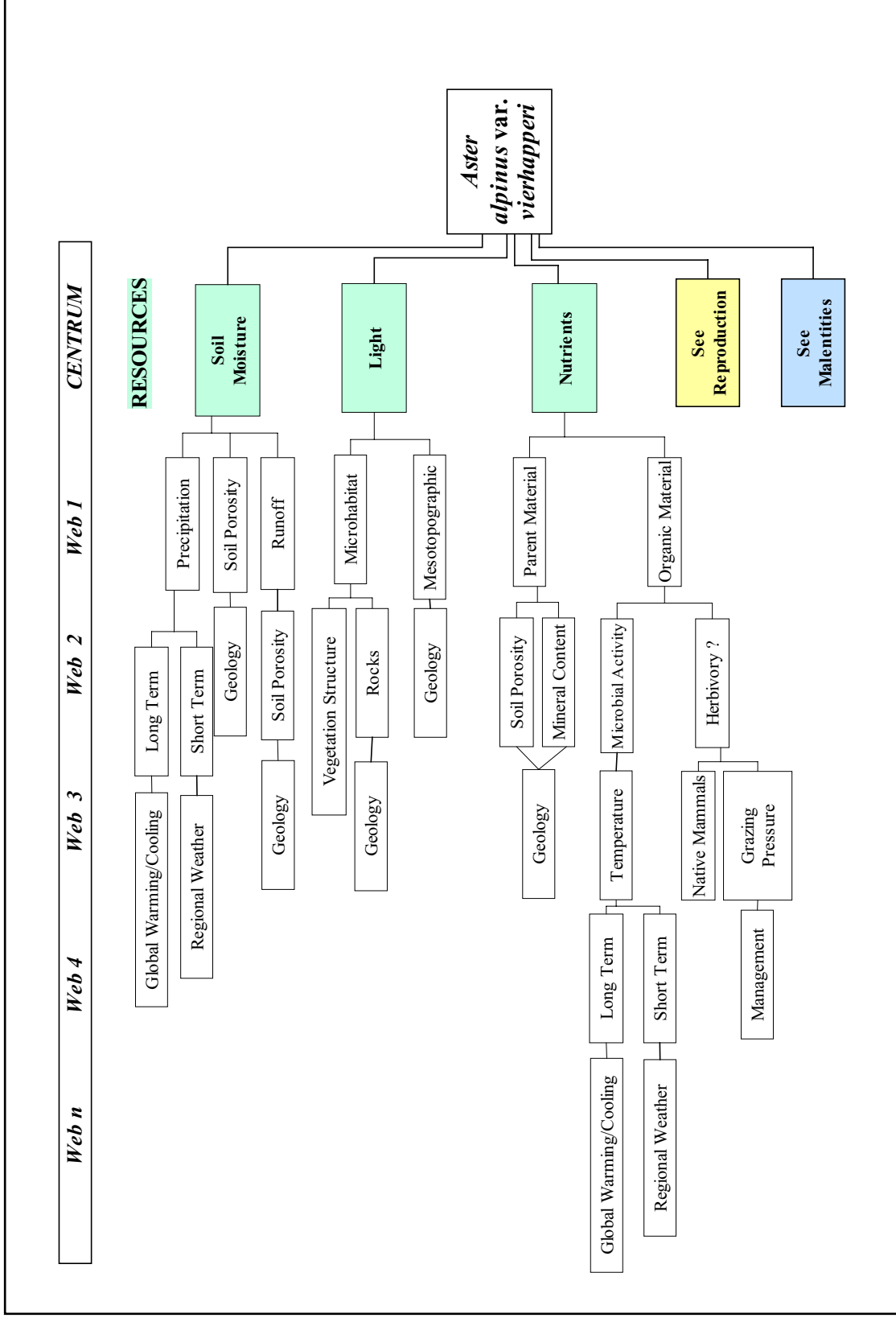
negatively affect the occurrence. Herbivory from either domesticated livestock or native mammals and insects may cause damage through trampling, seed predation, or leaf damage. Competition from invasive species, possibly introduced through grazing or recreational hiking, may have a negative effect upon the ability of *A. alpinus* var. *vierhapperi* to occupy available habitat. In addition, trampling from recreational hikers or ORV use may present a threat to *A. alpinus* var. *vierhapperi*. Air pollution, including acid rain, silver residue from cloud seeding, and the development of greenhouse gases, may also have a negative effect upon the alpine community and *A. alpinus* var. *vierhapperi*.

## CONSERVATION

### Threats

The limited abundance and disjunct distribution of *Aster alpinus* var. *vierhapperi* on National Forest System lands within Region 2 generates a concern for the viability of this taxon. Region 2 occurrences of this taxon are remote and small or of unknown size, and the resulting lack of information makes it difficult to identify threats to *A. alpinus* var. *vierhapperi*. The main viability concern for this taxon is the loss of occurrences from management actions and/or recreational activities. Most alpine and montane areas are subject to a range of general threats, such as grazing, surface mining, and impacts from recreational use, such as trampling or soil disturbance from hikers, four-wheel drive vehicles, off-road vehicles (ORVs), or snowmobiles. Recreational use by ORVs at occurrence 003\*CO is currently the only documented existing threat. The remote locations of the other known occurrences provide some degree of protection; however, land managers may be unaware of occurrences and unable to make informed decisions concerning management actions.

Occurrences of *Aster alpinus* var. *vierhapperi* may be at risk from environmental or demographic stochasticity due to the small neighborhood size of populations. Threats to reproductive processes (e.g., inadequate pollinator activity, possible outbreeding depression through a hybridization event, lack of safe sites for germination or seedling establishment) as well as unknown barriers to gene flow may pose possible risks to this taxon. Other threats that may affect *A. alpinus* var. *vierhapperi* include environmental factors, such as global warming, nitrogen deposition, or silver iodide pollution. The following is a discussion of specific threats in order of likely impact to *A. alpinus* var. *vierhapperi*.



See  
Reproduction

See  
Malentities

**Figure 7.** Resources centrum for *Aster alpinus* var. *vierhapperi* envirogram.

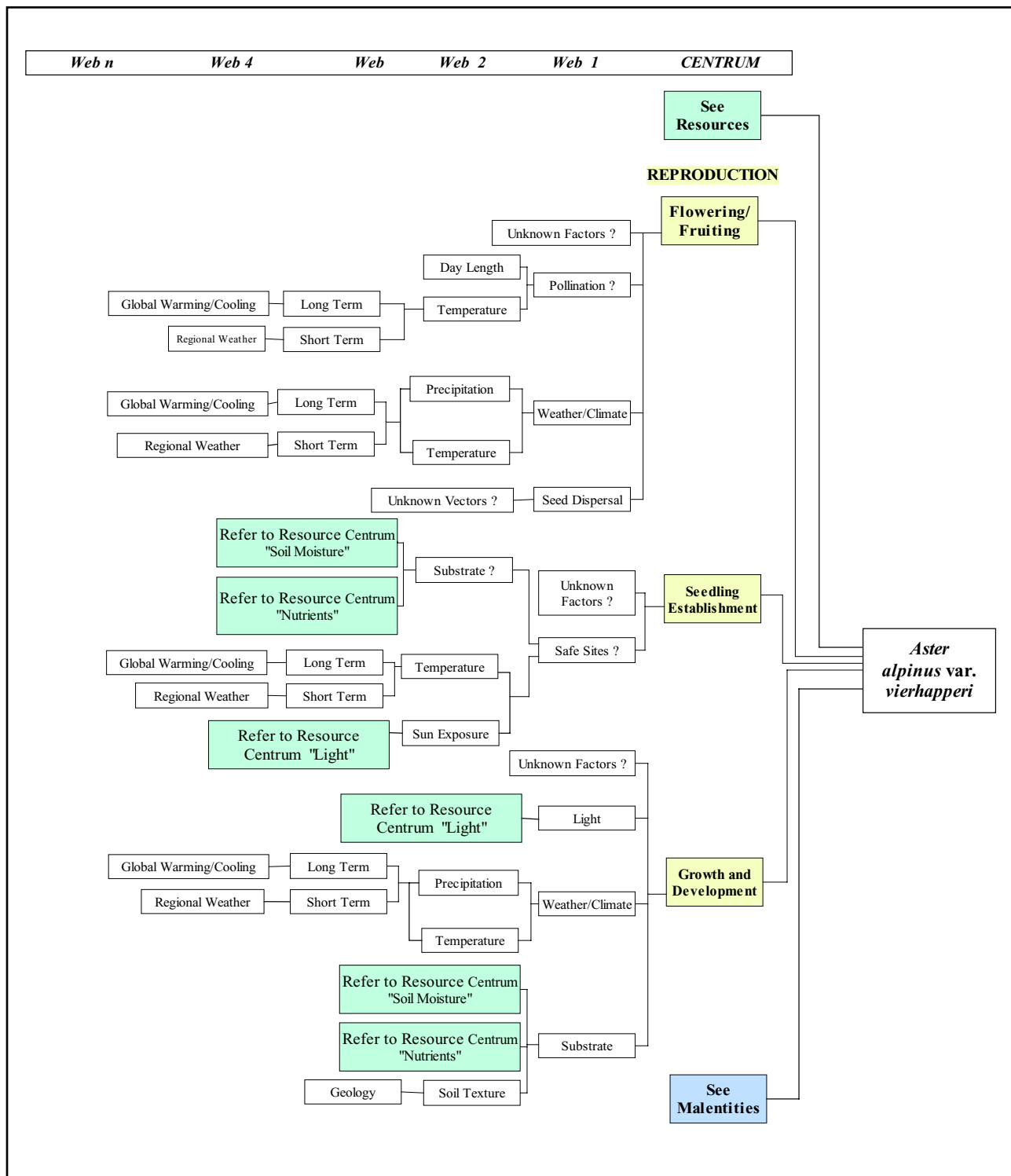
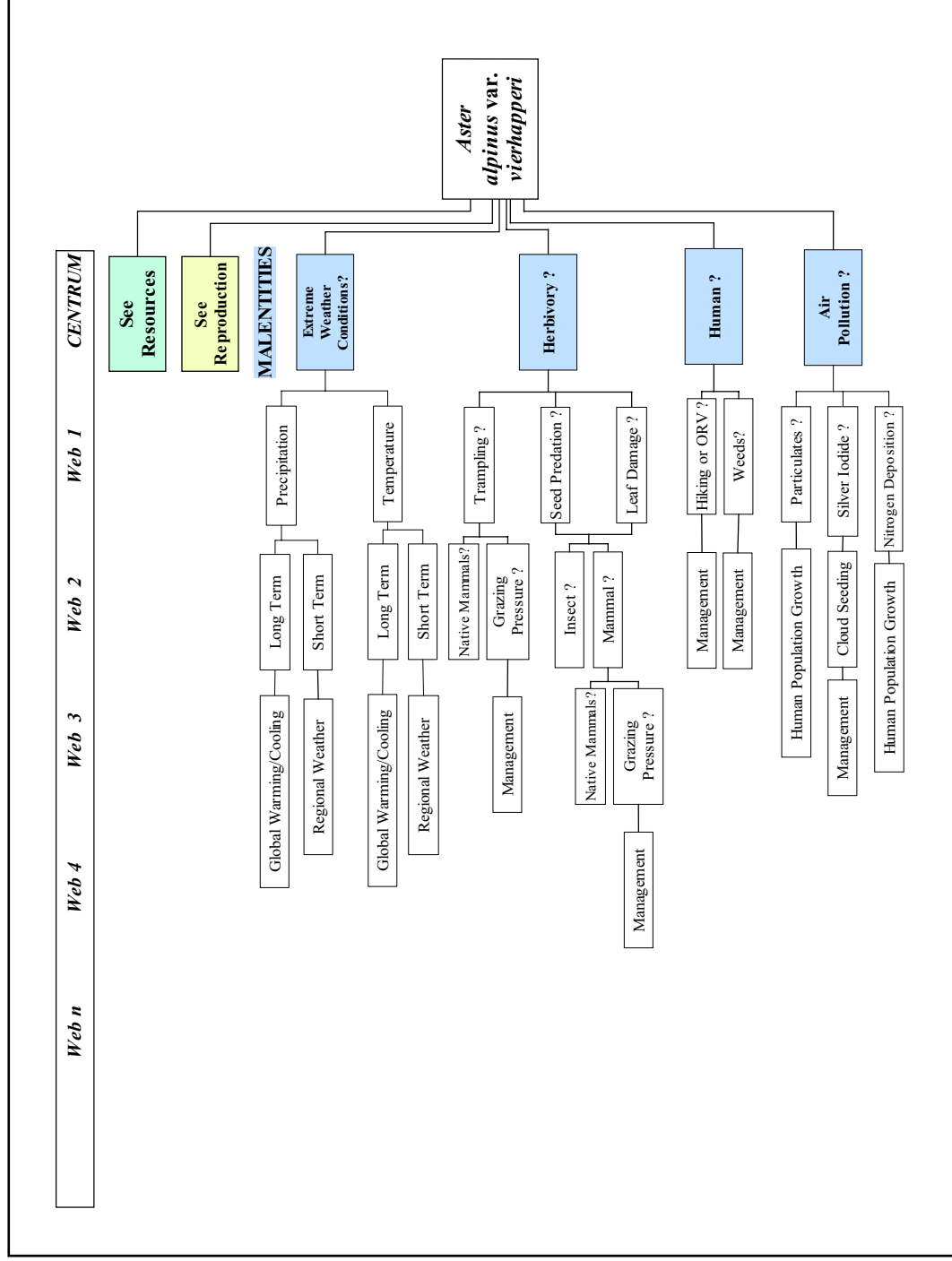


Figure 8. Reproduction centrum for *Aster alpinus* var. *vierhapperi* envirogram.



**Figure 9.** Malentities centrum for *Aster alpinus* var. *vierhapperi* envirogram.

## Recreational activities

Recreation in the proximity of occurrences of *Aster alpinus* var. *vierhapperi* consists primarily of four-wheel drive vehicle use, ORV use, and hiking. Impacts from vehicle use include habitat fragmentation, increased erosion, and direct impacts to individual plants from trampling. One of the five known Colorado occurrences (003\*CO) is located adjacent to Forest Service Road #353 in the Kingston Peak area of the Arapaho and Roosevelt national forests. This occurrence is probably the one most threatened by recreational activities in Colorado. An observer witnessed repeated crossings of the occurrence by ORVs (Yeatts personal communication 2004). The Wyoming occurrence (001\*WY) is adjacent to U.S. Highway 212 on Beartooth Pass. A parking area provides the opportunity for pedestrian trampling of individual plants, but direct impact to individuals by trampling has not been documented to date. No search was conducted to determine if *A. alpinus* var. *vierhapperi* occurred in inventoried roadless areas or not. Should occurrences of *A. alpinus* var. *vierhapperi* be located within such an area, it would provide a reduction in management actions and recreational activities, thus reducing the threat.

Snowmobiles primarily change snow characteristics including air pockets, compaction (density), and character and timing of snowmelt. These effects appear to be quite different from the crushing, habitat destruction, introduction of non-native plants, and other effects from summer motorized ORV use. Both summer and winter motorized recreation involves the use of petroleum fuels and lubricants that are introduced into the environment both in the air and directly onto the land and water. Further discussion of the effects of snowmobiles on the environment can be found in Neumann and Merriam (1972), Knight et al. (1975), Keddy et al. (1979) and Bilbrough et al. (2000).

## Grazing

Some areas in the alpine are allotted to summer sheep grazing. Palatability of *Aster alpinus* var. *vierhapperi* has not been documented, but since it is associated with the dry meadow community in the alpine, this taxon may be exposed to more sheep grazing than if it were found in ice field or late snowmelt microhabitats. Secondary grazing impacts from trailing, soil compaction, erosion, and spread of noxious weeds may be important. In general, the rugged topography and isolation from water sources minimize

direct threats of grazing to *A. alpinus* var. *vierhapperi*. The occurrence on the Rio Grande National Forest (CO\*002) is located within a vacant inactive sheep allotment, West Willow S & G. The adjacent allotment, Miner Creek S & G, is located approximately 800 m (0.5 mile) west of the occurrence. This is an active sheep allotment, but no grazing is currently taking place (Becenti personal communication 2004).

There is no sheep grazing near the Kingston Peak occurrence (CO\*003) (Lindsay personal communication 2006), but the occurrence is within an active cattle grazing allotment on the Boulder Ranger District. Although cattle may not graze within this high elevation occurrence, it is possible that they do. No additional information was provided concerning the extent of grazing near occurrences of *Aster alpinus* var. *vierhapperi* on the Arapaho and Roosevelt national forests.

Kantrud (1995) indicates that livestock apparently avoid asters. Biondini et al. (1998) indicate that grazing increased the relative composition of *Poa pratensis* (Kentucky bluegrass) and *Achillea millefolium* (yarrow), but reduced the relative composition of *Bouteloua gracilis* (blue grama) and *Aster ericoides* (heath aster). Sullivan (1992) reports that 30 years after study plots had been retired from heavy grazing, *A. laevis* (smooth aster) was found only on the edges of the sites nearest undisturbed native prairie. This literature indicates that another *Aster* species may be vulnerable to livestock grazing. Tallgrass prairie habitat differs from alpine, however, in length of growing season, primary productivity, and environmental conditions including temperature and moisture (Barbour et al. 1987). Alpine plants are likely more vulnerable to overgrazing than tallgrass prairie plants.

## Mining

No reports of direct impacts to *Aster alpinus* var. *vierhapperi* from mining activities have been reported. One historical location (004\*CO) is located near the old Britannic Mine in the Guanella Pass area, but this occurrence was documented in 1871 and has never been relocated. A search for *A. alpinus* var. *vierhapperi* in the area of this mine should be conducted to verify the presence or absence of the plant. Patented mining claims could occur on or near occurrences of *A. alpinus* var. *vierhapperi*. No evaluation of the location of occurrences with respect to ownership of mining claims on National Forest System lands was conducted for this assessment. Should mining occur near an occurrence, impacts may include habitat fragmentation, alteration

of hydrology, increased erosion, and direct impacts to individual plants from construction and operation of roads and mines.

#### Other threats

Other potential threats to the taxon include native herbivory, competition from invasive species, extreme weather conditions, fire, loss of gene flow, global warming, and air pollution.

Herbivory may occur from native fauna including mammals and insects. The montane location (005\*CO) may be subjected to herbivory from deer and elk. Likewise, the alpine occurrences may be subject to damage by small mammals such as pikas or marmots. Native herbivory could result in seed predation or leaf damage. No observations have been made concerning leaf or seed damage from insects or clipped stems indicating small mammal harvest at any of the *Aster alpinus* var. *vierhapperi* occurrences.

The topographic location of several occurrences provides a degree of isolation from interactions with invasive species, but recreation and grazing have potential to introduce invasive species even in remote locations. No invasive species have been reported within the known occurrences of *Aster alpinus* var. *vierhapperi*. Invasive species often dominate in post-fire communities and are often introduced into allotments via grazing livestock.

A change in climate may affect pollinator activity and optimal conditions for flowering (e.g., water supply, temperature). Extreme drought may affect flowering, seed set, germination, seedling establishment, and dispersal. An investigation of the effects of snow-pack on flowering showed that decreased snowfall would result in colder temperatures, which caused a reduction in seed set of *Delphinium nelsonii* (twolobe larkspur) through delayed flowering by slowing flower formation or causing damage during floral development (Inouye and McGuire 1991). In addition, changes in precipitation due to climate change were found to negatively affect the long-term abundance and persistence of *Androsace septentrionalis* (pygmyflower rockjasmine), a common alpine species (Inouye et al. 2003).

Fire may pose a threat to the occurrence located in the Golden Gate Canyon State Park (005\*CO). This occurrence is in a montane aspen forest, and it is possible that this habitat could burn. It is not known if *Aster alpinus* var. *vierhapperi* can survive a surface fire. The rhizomatous root system may provide

a mechanism for fire survival, depending upon the intensity of the fire.

Occurrences of *Aster alpinus* var. *vierhapperi* may be at risk from environmental or demographic stochasticity due to small neighborhood size. Environmental stochasticity may affect reproductive processes such as pollinator activity (Menges 1991). Any event that may cause habitat fragmentation (e.g., road or trail building) may impede pollinator activity and consequently reduce gene flow. Hybridization events have been reported in old world species of *A. alpinus*, and members of the Astereae have been known to readily hybridize. It is not known if *A. alpinus* var. *vierhapperi* undergoes hybridization or what the possible effects may be. However, hybridization events can disrupt gene flow among populations.

Global warming has been identified as a potential threat to alpine communities and could severely affect plants trapped on high mountain islands. Both lower elevation and alpine snow covers are very sensitive to changes in climate. Theoretically, snow cover could be reduced in extent, duration, and depth. Global warming could result in an alteration of timberlines encroaching on alpine habitats (Colorado Department of Public Health and Environment 1998).

Nitrogen emissions from fixed, mobile, and agricultural sources have increased dramatically along the Front Range of Colorado (Baron et al. 2000). A study of nutrient availability, plant abundance, and species diversity in alpine tundra communities determined that an addition of nitrogen resulted in an increase in species diversity in a dry meadow (Theodose and Bowman 1997). Increased nitrogen may provide a potential threat to *Aster alpinus* var. *vierhapperi*. However, a recent study reported dry alpine meadow communities and alpine fellfield habitats store only a small fraction of available snowfall and precipitation due to wind exposure. Therefore, the magnitude of nutrient enrichment from nitrogen deposition is less in alpine areas than in those mesic areas. As a result, little change in species composition and plant productivity due to nitrogen deposition might be expected to occur over time in the drier habitats (Seastedt et al. 2004) where *A. alpinus* var. *vierhapperi* occurs.

The effectiveness of cloud seeding is still in debate. It may be harmful to flora, fauna, and water through introduction of silver iodide into ecosystems (Irwin et al. 1998). It is an expensive process, and only large corporations, such as those that manage ski areas, have the resources to do cloud seeding. It has occurred

near Vail, Durango, Telluride, and Beaver Creek in Colorado. It is currently not a factor in the Beartooth Mountains of Wyoming. It has been speculated that cloud seeding a west to east moving storm in one area may decrease the precipitation that a given storm produces in areas east of the seeded region. Three of the five Colorado occurrences (001\*CO, 003\*CO, and 004\*CO) are located within a 25-mile radius of several ski areas such as Winter Park, Loveland Pass, and Vail. The dynamics of cloud seeding is poorly understood, but the effects of silver on biological systems has been well documented (Irwin et al. 1998). The Billings Gazette (Associated Press 2005) reported that a Wyoming legislative committee approved a cloud-seeding study in the Medicine Bow, Snowy Range, Sierra Madre, and Wind River Mountains in Wyoming. None of these mountain groups has known occurrences of *Aster alpinus* var. *vierhapperi*. However, the continental divide runs across the Wind River Range, and potential occurrences may be present.

### **Conservation Status of *Aster alpinus* var. *vierhapperi* in Region 2**

The six Region 2 occurrences and four occurrences in Idaho (all over 20 year old records) are the only documented occurrences of *Aster alpinus* var. *vierhapperi* in the contiguous United States. Five of the six documented Region 2 occurrences were reported from National Forest System lands, one in Wyoming on the Shoshone National Forest and four in Colorado on the Arapaho and Roosevelt and the Rio Grande national forests. Only the Arapaho National Forest occurrence and an occurrence at Golden Gate State Park in Colorado have been relocated in the past 20 years. Total number of individual plants is estimated at 200+ at the Arapaho National Forest site; abundance figures are not known from any other occurrences.

*Aster alpinus* var. *vierhapperi* is not listed as a sensitive species in Region 2, nor is it designated as a species of special concern in any of the individual forests in Region 2 (refer to Management Status discussion above for specific details). This taxon was chosen to be the subject of an assessment because of limited knowledge concerning its distribution, habitat, population trends, and threats.

The known distribution of *Aster alpinus* var. *vierhapperi* is limited within National Forest System lands and poorly understood both regionally and globally. It is difficult to ascertain the viability of this taxon with so little information. Abundance data are minimal from Region 2 and from other

conservation organizations throughout the taxon's range. Demographic parameters, population structure, and ecological strategies are all biological aspects of *A. alpinus* var. *vierhapperi* that remain uninvestigated at this time. Only two of the six occurrences in Region 2 could be readily relocated (003\*CO and 005\*CO; Yeatts personal communication 2004). The remaining four have not been relocated in more than 20 years, and insufficient location data exist. Lack of information prevents any conclusions about determining habitat quality, estimating population trends, and pinpointing risks associated with reproductive mechanisms for this variety within Region 2 or throughout its range.

It is impossible to evaluate the effects of current management activities upon the alpine aster, because information in Region 2 is lacking. *Aster alpinus* var. *vierhapperi* is at risk from ORV use in the proximity of one occurrence. Other possible threats on National Forest System lands include grazing, non-motorized recreational use, competition from invasives, surface mining, and environmental changes due to global warming and succession.

The occurrence at Kingston Peak (003\*CO) appears to be viable and stable. It was included within the CNHP Kingston Peak potential conservation area designated in 1994. Potential conservation area designation does not carry any legal or regulatory status, but it does indicate that the area has particular conservation value. In this case, the primary value of the area is the presence of *Aster alpinus* var. *vierhapperi*. Information included at the time of designation indicates that threats to the species were present and that management would be needed within five years to preserve this species. No other information concerning the viability of the occurrences exists. No predictions about this plant's ability to buffer against environmental or demographic stochasticity can be made until more data are accumulated.

### **Management of *Aster alpinus* var. *vierhapperi* in Region 2**

Implications and potential conservation elements

Although this taxon appears to be sufficiently abundant and secure to be viable in its primary range, it is much less secure in disjunct occurrences in Colorado, Wyoming, and Idaho. Of the ten documented occurrences, only two were located in the past 20 years. It is possible that other occurrences remain but have not been relocated because of inadequate location

information. However, given current information, it appears that management of the taxon in Region 2 is critical for its persistence outside its primary range in Alaska, Canada, and the Altai. Since the population trend for the species may already be in decline, its viability and survival in Colorado and possibly the contiguous United States may depend on the coordinated efforts of managers on the Arapaho National Forest and Golden Gate State Park.

No federally protected areas have been designated that include the conservation of this taxon or its habitat as an explicit goal. The primary concern for the viability of the variety within Region 2 is its limited distribution and the management of fragile alpine habitats. Occurrences of *Aster alpinus* var. *vierhapperi* in Colorado, Idaho, and Wyoming represent geographically isolated peripheral populations of a variety that is widespread in other portions of its range (central Asia in the Altai Mountains, Siberia, and east across Alaska and Canada to Ontario). Protection of peripheral populations of widespread species has been controversial. However, Erlich (1998) states that “species conservation depends upon protecting the genetic variability persistent throughout the range of the species.” Populations of *A. alpinus* var. *vierhapperi* in Colorado, Idaho, and Wyoming are disjunct from the primary population centers and represented only by small isolated occurrences. These peripheral populations may have distinct traits that may be crucial to the species by allowing adaptation in the face of environmental change (Lesica and Allendorf 1995). Collection of information and research concerning *A. alpinus* var. *vierhapperi* may be a lower priority than rare species with global rarity (G1 or G2); however, there is value in the protection of the taxon and its habitat on the southern edge of its range.

Management activities may have direct or indirect impacts to individuals or occurrences of *Aster alpinus* var. *vierhapperi*. Activities potentially occurring on USFS lands that may pose a threat to individuals or occurrences of *A. alpinus* var. *vierhapperi* include grazing, mining, recreation, and competition from invasive species. The consequences of management actions may include habitat fragmentation, soil compaction, erosion, trampling of individuals, or loss of fitness or niche. No experimental data are available on the response of this taxon to management actions.

#### Tools and practices

The most useful information acquired at minimal expense would be simple presence or absence surveys.

For many years, it was thought that this taxon was restricted to Colorado in the lower 48 states, but it has recently been shown to occur in northwestern Wyoming and in Idaho (Region 4). The Wyoming locality is approximately 4.0 km (2.5 miles) from the Montana border, so it is possible that *Aster alpinus* var. *vierhapperi* occurs in Montana as well. These surveys would include collecting accurate information on location and habitat characteristics, evidence of negative impacts, and estimating population numbers.

Alpine areas are difficult and time-consuming to access and survey. Certain areas of alpine tundra, particularly those areas easily accessible along the Front Range of Colorado, have been intensely inventoried. Nevertheless, considerably more acres of alpine habitat have never been adequately surveyed, partly because botanists have not ventured into areas far from easily reached access points such as roads and trails (Weber personal communication 2004) and because support for such intensive surveys is lacking. In Region 2, there are thousands of acres of alpine tundra between the known occurrences in Mineral County, Colorado and Park County, Wyoming, most of which have not been inventoried for this variety. The Flora of the Rocky Mountains Project (Hartman 1992) has successfully accomplished intensive surveys in some of these areas.

The importance of inventory cannot be overstated with regard to this taxon. The untrained eye is very likely to overlook this variety in the field, particularly if it occurs with species of *Erigeron* (see morphological characteristics in Biology and Ecology section). Misidentifications of *Aster alpinus* var. *vierhapperi* have occurred. Future surveys for this taxon should include herbarium searches. It is possible that more documented occurrences of this taxon can be found on mislabeled herbarium sheets.

Population monitoring should be designed to ascertain parameters of the plant’s life history (e.g., generation time, net reproductive rate, age distribution, potential reproductive output lost to abortion and predation) efficiently. Periodic estimates of population size alone may not provide adequate information for management decisions (Elzinga et al. 1998). Factors affecting seedling establishment need to be determined since this is a critical life stage for any alpine species.

Additional quantitative data that document the condition of the community where *Aster alpinus* var. *vierhapperi* occurs (i.e., plant composition, community structure and function) would provide information should an increase or decline in occurrences take place.

This information may also provide clues as to possible limiting factors controlling the distribution of the variety. Common variables to be measured include cover or density of all plant species; demographic parameters of important species; soil surface conditions, including percent cover of rock; and microhabitat observations, including slope, aspect, and geologic substrate. Soil temperature information may provide valuable insight to seed germination requirements and possible safe sites. Measurement and scheduled remeasurement would provide a long-term ecological study to document rates and types of change that can occur in response to natural processes such as succession and disturbance (Elzinga et al. 1998).

Habitat monitoring describes how well an activity meets the objectives or management standards for the habitat (Elzinga et al. 1998). Habitat monitoring is most effective when research has shown a clear link between a habitat parameter and the condition of a species (Elzinga et al. 1998). Without additional knowledge of specific factors controlling the growth and distribution of *Aster alpinus* var. *vierhapperi*, it would not be possible to establish a habitat monitoring program at this time.

The mission of the Center for Plant Conservation is to conserve and restore the rare native plants of the United States. No plant material for this taxon has been stored with the Center for Plant Conservation.

### ***Information Needs***

Continued efforts in the location of other occurrences of *Aster alpinus* var. *vierhapperi* by use of presence/absence surveys as described above and census counts may provide additional information concerning its distribution to assist in the formulation of conservation strategies for Region 2.

Recommendations for further study and beneficial actions include:

- ❖ initiate field surveys to relocate and monitor known locations, and survey for new occurrences; pertinent field data would include estimates of population size and spatial extent; inventory would also include herbarium searches for misidentified specimens.
- ❖ evaluate the reproductive and ecological characteristics of the variety including pollination mechanisms, seed germination, seedling establishment, herbivory, flowering/fruiting, and dispersal vectors in order to provide a basis to assess further the factors controlling its growth.
- ❖ collect quantitative data relevant to community structure and composition in order to provide a baseline for use of habitat monitoring in the future
- ❖ evaluate demographic parameters (i.e., vital rates, recruitment, survival, reproductive age, lifespan, or proportion of populations reproducing, seed viability, seed bank dynamics, longevity)
- ❖ initiate field monitoring to determine extent of impacts (if any) of management activities and natural disturbance to the variety
- ❖ periodically assess occupied and potential habitat for active and potential threats from human related activities
- ❖ develop management direction if disturbance to the species is found
- ❖ reconsider sensitive species status in Region 2, given the extremely limited numbers of occurrences and individual plants known and the importance of occurrences on National Forest System lands.

## DEFINITIONS

**Alleles:** Any of the different forms of a gene occupying the same locus (Lincoln et al. 1982).

**Altai:** Large mountain system situated in the southern part of Siberia, at the border between Russia and Kazakhstan and Mongolia and China.

**Anemophily:** Dispersed or pollinated by wind (Lincoln et al. 1982).

**Apomixis:** Reproduction without fertilization, in which meiosis and fusion of the gametes are partially or totally suppressed (Lincoln et al. 1982).

**Capitulum:** A small flower head, consisting of a dense cluster of sessile or subsessile flowers; the involucre inflorescence of the Asteraceae (Harris and Harris 1994).

**Chartaceous:** With a papery texture, usually not green (Harris and Harris 1994).

**COLO:** University of Colorado Museum, Boulder, Colorado (Holmgren and Holmgren 1998)

**Entomophily:** Pollination by or dispersed by the agent of insects (Lincoln et al. 1982).

**Environmental stochasticity:** Variation over time in a population's operational environment (Menges 1991).

**Fellfield:** A type of alpine/tundra ecosystem having sparse dwarfed vegetation and flat, very stony soil (Lincoln et al. 1982).

**Generation time:** The mean period of time between reproduction of the parent generation and reproduction of the first filial generation (Lincoln et al. 1982).

**Hemicryptophyte:** A perennial plant with renewal buds at ground level or within the surface layer of soil; typically exhibiting degeneration of vegetative shoots to ground level at the onset of the unfavorable season (Lincoln et al. 1982).

**Heterozygosity:** Having two different alleles at a given locus of a chromosome pair (Lincoln et al. 1982).

**Homozygosity:** Having identical alleles at a given locus of a chromosome pair (Lincoln et al. 1982).

**Imbricate:** Overlapping like tiles or shingles on a roof (Harris and Harris 1994).

**Inbreeding:** Mating or crossing of individuals more closely related than average pairs in the population (Lincoln et al. 1982).

**Inbreeding depression:** Reduction of fitness and vigor by increased homozygosity as a result of inbreeding in a normally outbreeding population (Lincoln et al. 1982).

**KHD:** Kathryn Kalmbach Herbarium, Denver, Colorado (Holmgren and Holmgren 1998).

**Longevity:** The average life span of the individuals of a population under a given set of conditions (Lincoln et al. 1982).

**MT:** Herbar Marie-Victorin, Université de Montréal, Montréal, Quebec, Canada (Holmgren and Holmgren 1998).

**Metapopulation:** a group of different but interlinked populations, with each different population located in its own, discrete patch of habitat.

**Phytomicroclimate:** The environment created within the confines of a plant body, and within the various parts of the plant body, such as leaf or stem (Thilenius 1975).

**Primordia:** The early cells that serve as precursors of an organ to which they later give rise to (Allaby 1992).

**Outcrossing:** Mating or crossing of individuals that are either less closely related than average pairs in the population, or from different populations (Lincoln et al. 1982).

**RICK:** Herbarium, Department of Biology, Brigham Young University – Idaho, Rexburg, Idaho (Holmgren and Holmgren 1998).

**RM:** Rocky Mountain Herbarium, Laramie, Wyoming (Holmgren and Holmgren 1998).

**Self-compatible:** Used of a plant that can self-fertilize (Lincoln et al. 1982).

**Selfing:** Self-fertilizing or self pollinating (Lincoln et al. 1982).

**Sink:** A population patch, in a metapopulation, that does not have a high degree of emigration outside its boundaries but, instead, requires net immigration in order to sustain itself.

**Source:** A population patch, in a metapopulation, from which individuals disperse to other population patches or create new ones.

**Vital rates:** The class-specific annual rates of survival, growth, and fecundity (Morris et al. 1999).

**WAT:** Herbarium Biology Department, University of Waterloo, Waterloo, Ontario, Canada (Holmgren and Holmgren 1998).

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